DISCOVERY

Monthly Notebook

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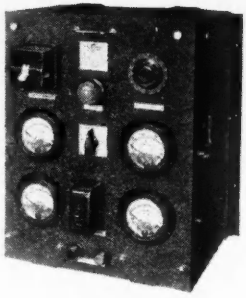

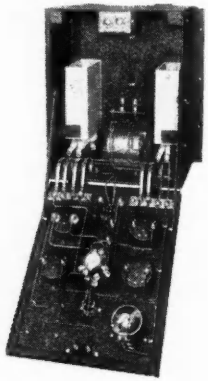

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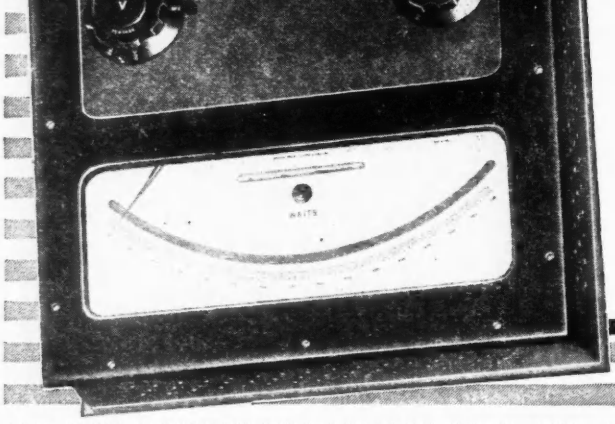

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The Progress of Science

Who are the Great Scientists?

A RADIO talk by Lord Samuel entitled "The Mark of Greatness", held some scientific interest because he mentioned two scientists whom he considered to come within the category of the truly great. The first—an obvious choice—was Einstein, of whom Lord Samuel said:

"In the world of science we cannot fail to rank Einstein among the great ones. He is a pioneer, original and daring, in that most difficult of all regions, the abstract province where physics and philosophy meet. And his mind ranges wide. He thinks constantly and deeply on the course of human affairs, and, as his latest book* shows, makes his fame an opportunity to win the ear of mankind for his earnest pleading for social justice and international peace."

The other scientist he included in his list of great men was Rutherford: "also one of the greatest—it was truly said that he was 'an unself-conscious, victorious personality'." To both Einstein and Rutherford did Lord Samuel apply this remark—"they are great men who are modest because they continually compare themselves, not with other men, but with that idea of the perfect which they have before their mind."

It would be interesting to have readers' views as to which *living* scientists deserve to be classified as 'great'. It is difficult to find any sort of criterion of greatness in the sense that Lord Samuel used the word; certain it is that research achievement of the class that wins, or merits, the winning of a Nobel Prize is not enough by itself to justify the use of the adjective. We would welcome letters on this matter; a DISCOVERY 'Gallup' poll might yield some interesting results.

The Growth of Television

FACTS and figures recently released by the B.B.C. show a steady increase in the number of television licensees, the total at the end of December being 555,000. Unlicensed sets probably account for a large number of additional viewers, this extra figure may be up to 10% of the official figure. It is estimated that by 1952 the total will exceed a million, owing to the additional stations which will be operating then.

The time-table for the erection of the new television stations provides for a service for approximately 85% of Britain's population by 1954. Holme Moss will be completed by mid-1951, the Scottish station at Kirk o'Shotts will be ready by the end of 1951, and in 1952 stations will be opened near the Bristol Channel, Newcastle, and Southampton. The Holme Moss station will equal Sutton Coldfield in power, and will be the second most powerful television station in the world.

Equipment will be increased commensurately with the increase in coverage. The studio camera channels available will be fourteen in 1951, against six at the resumption of the service after the war. The Outside Broadcasts Units, originally two, will be increased to five.

Finally, the estimated capital expenditure will be no less than £1,200,000 in 1950–51, which, with an estimated revenue expenditure of £1,5000,00, will yield £2,700,000 for the expansion of the service. The Director-General of the B.B.C. is prepared to sanction a considerable increase in programme expenditure in order to attract high quality talent to the studios and improve the studio presentation.

These estimates were probably prepared before the Defence Programme was announced, and it is to be expected that the shortage of raw materials will slow down the rate of completion of the stations.

The Radio Industry's production schedule was also planned to keep pace with the development of television over the country, and so far it has been possible to take up the defence load without seriously affecting the supply of civilian receivers. Nevertheless it will be too much to hope that the combined shortage of raw material and an increased rearmament programme will leave the industry unaffected for long.

During the past few months a bitter controversy has been taking place in America on the relative merits of three-colour television systems which have been developed by three rival corporations and which are mutually exclusive.

First in the field was Dr. P. C. Goldmark, whose colour system involving a rotating colour filter in front of the

* *Out of my Later Years*; this collection of miscellaneous essays is published in Britain by Thames & Hudson, price 15*s*.

screen was demonstrated some years ago. The Columbia Broadcasting System, of which he is the chief television engineer, has been licensed by the Federal Communications Commission too operate a public colour television service.

Strong objection to this virtual monopoly has been taken by the Radio Corporation of America, who have developed an 'all-electronic' system using three cathode ray tubes, and by Color Television Inc., who use a single cathode ray tube with patches of coloured phosphors on the screen.

Not only do the three systems differ in the method of reproduction but the process of scanning is different, thus making it impossible to receive alternative systems on the same equipment.

The Columbia system transmits three colour 'fields' in sequence, the image at the transmitting end being separated into the three primary colours by means of a rotating filter in front of the camera. At the receiver these fields are reproduced on the screen of a single cathode-ray tube, in front of which is a colour filter similar to that at the transmitter and rotating synchronously with it. It is claimed that the single optical and electrical system employed eliminates faulty registration such as would be possible in a three-tube system.

An inherent defect in the system is that it transmits a complete field in one colour before the next succeeds, and therefore a quickly moving object may be accompanied by colour fringes. To avoid flicker the field scanning rate is increased to 144 fields per second, or 24 complete colour frames per second, compared with the American standard of 60 fields per second for monochrome pictures. This requires a special adapter to convert existing receivers for colour.

The R.C.A. system transmits the three primary colours dot by dot—the so-called 'dot-sequential system'—and the camera at the transmitter has three separate tubes on which a dissected image of the scene is directed through filter mirrors. Each tube is connected in turn to the transmitter by an electronic switch so that the dots succeed each other at the rate of 3,580,000 per second. At the receiver the image is formed by using three tubes, each with a different coloured phosphor, giving three separate images which are recombined optically on the screen.

The dot system compares favourably with the standard monochrome system for detail and it is capable of producing a black-and-white picture on existing receivers without modification. The National Bureau of Standards has shown that theoretically the system is equivalent to Kodachrome colour film, but the use of three colour tubes gives rise to optical and electrical errors in the transmitted pictures.

The third system, that of Colour Television Inc., uses a 'line-sequential' scanning system in which the three colours are transmitted line by line. It is thus intermediate between the two just described. At the standard scanning rate of 60 fields per second the complete colour pictures per second are only 10, which introduces serious interline flicker. The flicker-brightness relation for large areas of colour is very good, and the picture is free from colour fringing.

An independent committee has pronounced that the C.B.S. colour system approaches nearest to the realisation of a satisfactory public colour television service but the rivalry is unabated and further research is being undertaken to remove the defects in the other scanning systems. The effect of all this on British developments will be easily understood, and the final result of the American competition is being eagerly awaited.

The Chromatic Chameleon

A CORRESPONDENT has asked if it is really true that a chameleon changes its colour to suit its surroundings and, if so, how it is done. The answer to the first part is a qualified yes, for though the animal would not be able to go quite so far as to develop little red discs on a glossy green back to match a sprig of holly, it does make an astonishing variety of changes, that deserve serious attention.

The answer to the second part of the question is more difficult, for most of the information available has been until fairly recently in the long history of the creature, in the form of globe-trotters' wide-eyed tales.

An approach to a scientific study was made by a famous biologist, Brücke, just a hundred years ago, and many of his experimental findings, ignored for many years, have been verified by repetition under carefully controlled conditions. He said that the colour changes were controlled by nervous mechanisms, but biologists raised the distracting theme of hormones and secretions some thirty years ago, and they were so convincing, and their theories became so much the vogue, that many workers were persuaded. G. H. Parker of Harvard, a champion of the hormone theory—that an animal's colour-producing cells are actuated by secretions such as adrenaline, admitted in 1948, however, that in the case of a chameleon the evidence was not enough to support him, an admission that carries the implication that it is the theory of Brücke that is right and that of all the others wrong for reptiles in general, though it is doubtful if many biologists would admit this implication at present. For the chameleon at least the advocates of a nerve-reaction theory have triumphed—the theory that an animal's colour-producing cells are actuated by nervous control.

This triumph, in the case of the chameleon, is due largely to the work of two South African biologists working together, Alexander Zoond and Joyce Eyre. In 1934 and 1935 (in the *Philosophical Transactions* of the Royal Society and the *Journal of Experimental Biology* respectively) they made the most convincing case so far (and incidentally the only serious work on the chameleon since the times of Brücke) and submitted some of the work of the hormone-theory addicts to severely critical examination, especially in the contradictions involved and the failure to observe the essential first requirement of any experiment—the control of conditions and the realisation of the relevance of all possible factors.

A chameleon is a lizard of tropical and sub-tropical regions of the Old World. (There are no chameleons in the Americas.) There are many species ranging in size from a few inches to a couple of feet. It feeds on insects by remaining motionless with its mouth open and using its elastic sticky tongue, which works so quickly that it can hardly be seen, a fact that may have led to the learned Pliny's assertion that the chameleon lives on nothing but air, an opinion repeated by numerous writers, including Shakespeare, for nearly two thousand years.

FIG. 1. Colour changes in chameleons. A–D, *Chamaeleon vulgaris*; the other animal (top right) is *C. pumilus*. A, night colour, which is cream with irregular yellow patches. B, usual colour, grey-green with many small darker specks, and two series of pale brown patches on sides and one patch near ear. C, an excited specimen in act of shooting a fly: the pale brown patches have turned maroon brown, many golden spots have appeared on the green parts. D, a specimen, coloured like C, which was angered by pinching its tail. The body is inflated, the thick tongue makes the throat bulge out and the yellow spots have turned blackish green. (*Drawing by M. E. Durham, from volume on Amphibia and Reptiles by Gadow, in the Cambridge Natural History.*)

The chameleon's legendary power of changing colour owes much to romancers, especially those for whom the world was the Mediterranean basin, for most of the descriptions apply to the common chameleon that lives in North Africa. Its powers have often lent themselves to literary ornament, as when Socrates remarked of certain people that they changed about like chameleons.

The preoccupation of writers for over two thousand years, from Aristotle (who asserted that a chameleon changed colour when it took a deep breath) to writers of the nineteenth century, has obscured the fact that other animals have similar powers of automatic camouflage. The layman can, therefore, be forgiven if he thinks that the only animal with these powers is the chameleon. There are others—flatfish, for example, and frogs, and several lizards (other than chameleons)—some of them with the power of not only making changes in colour but also in pattern.

The variety of the chameleon's changes is undoubtedly greater than that of any other animal. So much so that Zoond and Eyre in their experiments had to give up using a fairly elaborate scale of colours and revert to a much simpler system. (In passing, one cannot help expressing regret that more biologists do not show awareness of the tremendous advances in colour measurement made by physicists in the past twenty years.) Part of the reason for the difficulty is the fact that there is some variation both in pigmentation and in pattern from one chameleon to another. Part of the reason is also the fact that the chameleon's skin has certain areas with different pigmentation properties. A 'standard model' is shown in Fig. 2 as

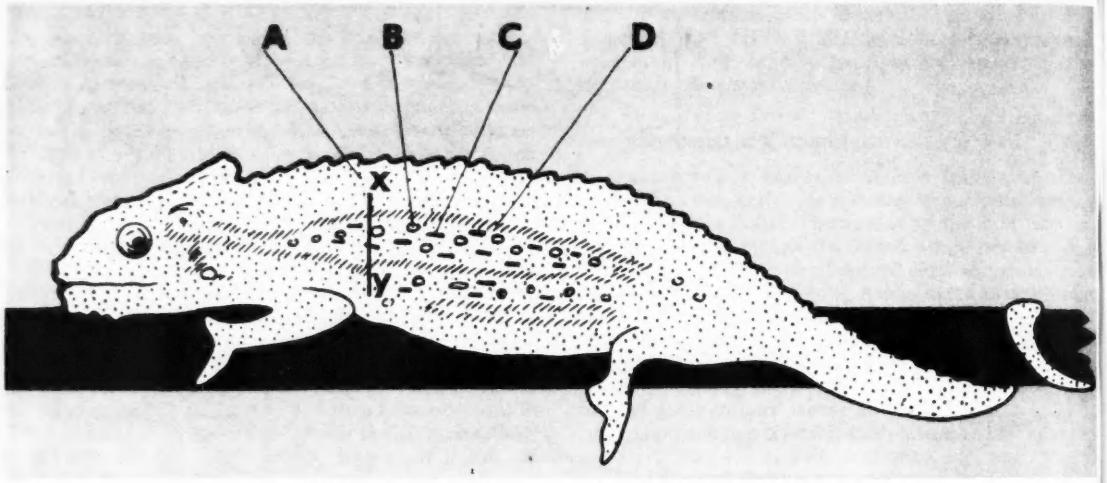


FIG. 2.—South African dwarf chameleon 'standard model'. A, *back*. B, *island*. C, *band*. D, *margin*. A section line is drawn at *xy*. (*After Zoond & Eyre.*)

broadly representative of the South African dwarf chameleon used in the work of Zoond and Eyre. They identified four different areas, which they called 'back' (the most generalised area), 'bands', 'islands', and 'margins'.

The skin under the microscope is seen to consist of many small protruberances or tubercles, and the system of pigmentation is different in the tubercles of the different regions named. An understanding of this arrangement is essential for anyone who wishes to know the range of colour changes available in the dwarf chameleon. In Fig. 2, A and B are marked. A section from *x* to *y* is reproduced very simplified and schematised, in Fig. 3. The tubercles of the 'back' have on top a layer of yellow pigment. Underlying this there is what Zoond and Eyre call the 'blue layer', not pigment but an arrangement producing an optical effect so that it is seen blue by reflected light but is almost colourless to transmitted light. The tubercles of the 'bands' have an upper layer of orange and have no blue layer. The tubercles of the 'margin' have no orange or yellow pigment, but only the blue layer. Below these layers in all the regions there is a layer that produces scattered white light by reflection. Embedded in this layer are cells that have black or dark brown pigment which can be concentrated in fine dots in the centre of each cell or can expand through the arms of each star-like cell. These cells loaded with dark pigment are called *melanophores*—literally, 'black-bearers'.

This arrangement accounts for the colouring of a chameleon's skin. It can easily be understood as a similar arrangement to that of a water-colour painting, for the incident light goes through the thin layers of transparent pigment to the white paper underneath and is then reflected back again. In the case of the chameleon, however, the blue is not a pigment but a colour seen only in reflected light. With the melanophores in the contracted state, therefore, as illustrated, some light striking the 'back' goes through the yellow layer and the blue layer and is reflected from the white layer. Such light will look yellow, for in going *through* the blue layer it is not changed to any great extent. Some of the light goes through the yellow layer and is reflected at the blue layer. Such light will look green, just as green is produced by mixing yellow and blue pigment. The resultant colour will depend on the ratio of yellow to green. With the melanophores in maximum contraction, the white layer is at its most reflecting state. The proportion of yellow to green is therefore high and the actual amount of yellow in the total light is small, for it is a thin layer and not dense. So the colour is a sort of off-white or cream. Now let the melanophores start to expand. They begin to obscure the white layer and make it more absorbing. The total amount of white light emerging is, therefore, cut down and at the same time the ratio of yellow to green is decreased. The result is at first a yellowish-green and then a green. The melanophores also expand through the layers to the surface and start to obscure the yellow and cut down the amount of light reflected from any of the layers. So the green gets darker and is eventually nearly black. Thus by the single operation of melanophore expansion the colours seen range from off-white through yellow and yellowish-green to green and dark green and finally black, when the melanophores have expanded to their greatest extent and obscured the yellow and blue layers. Similar processes go on in the bands and margin. In the 'bands' there is no blue layer at all and the top pigment is orange. The colours range, therefore, from a very unsaturated orange, i.e. a whitish-orange usually called 'fawn' by the observers, though orange to *brown*, which is orange mixed with black, and finally to black. In the 'margin' the colours range from a very white blue, i.e. a sort of grey, through blue to dark blue and finally black.

The stages of melanophore expansion are infinite, but if only four are taken as examples, the colours of the 'back', 'bands' and 'margin' respectively are: (1) cream, fawn, grey, (2) green, orange, blue, (3) dark green, brown, dark blue, (4) black, black, black. These four are enough to show the tremendous variety possible, all of them, it must be remembered, produced by only one mechanism, that of melanophore expansion.

In the unstimulated state the melanophores are contracted to their fullest extent. That is to say, in the absence of light, the chameleon is pallid, with just a suggestion perhaps of cream and fawn and grey. When light shines on it the melanophores are relaxed and start to expand. So in bright diffuse daylight the chameleon would, it seems, be black. But here another control comes into operation. This is perhaps the most significant discovery made by Zoond and Eyre. They have established that the eyes play a part in the control of the melanophores. Blind chameleons taken from darkness into daylight go through the several stages suggested above *irrespective of the background on which they are resting*. Intact animals, however, behave differently. If they are on white backgrounds when put in the daylight, they start to turn dark but soon turn back to pallid. If they are on black backgrounds, however, they do turn black. Thus the intact animals are black on a black background in daylight and light on a light background.

The amount of melanophore expansion is proportional to the intensity of the incident light. It would therefore be expected that in a dim light an intact animal would be pallid on a white background if there were no other mechanism operating. In actual fact, they are very dark. On a black background in a dim light they are even darker. This fact, quite contrary to expectations according to the then accepted theories, convinced Zoond and Eyre that the eyes operate a controlling mechanism. The colouring of a chameleon is thus a dual procedure. First the melanophores respond to incident light by a reflex action through the nerves and then a nervous mechanism acting through the retina controls them.

Other experiments were done to verify the theory in details. In the course of the work the authors showed that temperature was not a controlling factor at all within the limits of experienced warmth. It is true that at high temperatures the melanophores contract, but the temperature that has to be reached for this to happen is higher than the animals experience, for they normally get away into the shelter of foliage in the bright light of noon. If forced to stay in this great heat they struggle in discomfort and try to escape and eventually die. This fact is yet another nail in the coffin of existing theories on reptilian colour change. Indeed, on this wider question they observed finally that "the materials for the formulation of a general theory of reptilian colour change do not exist". This, coming after two and a half millenia of observation, should serve as a salutary warning to twentieth-century optimists.

"Endeavour" Prizes for Science Writing

As a contribution to the meeting of the British Association for the Advancement of Science to be held in Edinburgh in August 1951, Imperial Chemical Industries Ltd., publishers of the quarterly scientific review *Endeavour*, have offered the sum of 90 guineas to be awarded as prizes for essays submitted on a scientific subject. As the primary purpose of these awards is to stimulate younger scientists to take an interest in the work of the British Association and to raise the literary standard of scientific writing, the competition is restricted to those whose twenty-fifth birthday falls on or after June 1, 1951.

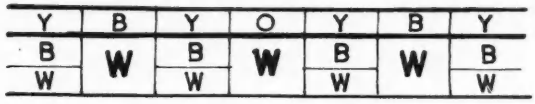


FIG. 3. Section *xy* from Fig. 2 schematised to show the succession of pigment arrangements. Y = yellow, O = orange, B = blue, W = white.

Four prizes will be awarded: a first prize of 50 guineas, a second prize of 25 guineas, a third prize of 10 guineas; there will be a special prize of 5 guineas for competitors who have not passed their eighteenth birthday on June 1, 1951.

The subjects for the essays are as follows:

1. *A Century of Science in Britain*
2. *Chromatography and is Possibilities*
3. *Biological Effects of Radiation*
4. *Science and Weather*
5. *Seaweeds and Their Uses*
6. *The Age of the Earth's Crust*
7. *Animal Locomotion*
8. *The Chemistry of Non-atomic Explosives*

The essays, which must be in English and typewritten, should not exceed 4000 words in length, and only one entry is permitted from each competitor.

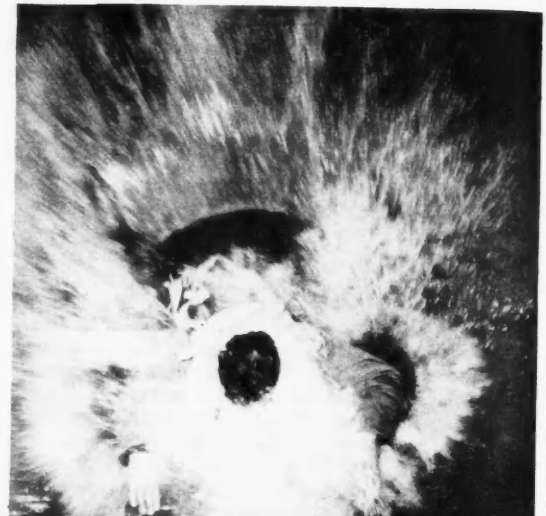
All entries should be addressed to:

The Assistant Secretary, British Association for the Advancement of Science, Burlington House, Piccadilly, London, W.1.

and the envelope should be clearly marked "*Endeavour* Prize Essay". The last date for receipt of entries is June 1, 1951. The essays will be judged by the editors of *Endeavour* in consultation with representatives of the British Association in Edinburgh in August 1951. The judges' decision is final, and they reserve the right to withhold all or any of the prizes should no entries of sufficient merit be received.

The essays should be submitted without signature. The competitor's full name and address and date of birth should be disclosed in a sealed covering letter attached to the essay and addressed to the Assistant Secretary of the British Association, who will acknowledge all entries. The names will not be disclosed to the judges until after the prize-winning essays have been selected.

In judging the results special attention will be paid to the way in which the subject is approached, and great importance will be attached to literary style. The competitor's age will also be taken into account. The essay winning the first prize will be published in *Advancement of Science*, journal of the British Association.



FIGS. 1 and 2.—A doctor, having inflated his 'Mae West', jumps into the observation water-tank.

FIG. 3.—The doctor in the water has jettisoned his parachute harness and the 'Mae West' is fully inflated.

Physiological Factors in Aviation

CHAPMAN PINCHER, B.Sc.

THE immediate limitations on aircraft flight are set by physiological rather than engineering factors. With the days of long-distance pilotless aircraft a long way in the future, it is the weaknesses of the human pilot rather than the defects of the flying machine which limit performance.

This fact first received official recognition in 1939 with the setting up of the R.A.F. Physiological Laboratory on the site of the Royal Aircraft Establishment at Farnborough, in Hampshire. Evidence that the physiological problems have become greatly intensified with the steadily improving performances of jet aircraft was abundant during a recent visit I made to the greatly expanded laboratory which is now known as the R.A.F. Institution of Aviation Medicine.

About one-third of the members of the large staff of this well-equipped Institute are medically qualified. Four of the staff doctors are also highly experienced pilots, and the Institute has its own flight of five aircraft.

Research is going ahead on four main problems:

(1) countering the hazards of flight at extreme altitudes;
(2) overcoming the gravitational effects of rapid velocity changes;
(3) preventing the exposure of pilots to temperature extremes;
(4) escaping from doomed aircraft.

The pilot flying at 50,000 ft. has to contend with an atmosphere of greatly reduced pressure and oxygen-content. (The *percentage* of oxygen is the same as at ground level—but the number of oxygen molecules available for respiration is much reduced.)

By spending several weeks at 18,000 ft. or so, mountain climbers can develop some physiological acclimatisation to anoxia (lack of oxygen in the blood) but this adaptation is so quickly lost on returning to ground-level that little use can be made of it by fliers.

At extreme altitudes—50,000 ft. for instance—pressurised cabins are essential. When exposed to the atmosphere at such a height a pilot loses consciousness from anoxia within 10 seconds, *even if he is breathing pure oxygen.*

The engineering problems of pressurised cabins have been satisfactorily resolved for civil flying, but they still weigh heavily in the minds of those concerned with combat aircraft. A jettisoned cockpit-canopy or a shell-torn cabin would expose high-flying aircrew to a sudden and severe decompression.

To discover safeguards against these risks the R.A.F. medical scientists have fitted up a big decompression chamber at Farnborough. Air conditions at 50,000 ft. can be simulated in this chamber and the doctors can test out experimental safety equipment on themselves.

I watched them stage a test of a new 'oxygen-waistcoat' designed to protect pilots against the effects of sudden decompression. The waistcoat is a double-walled gas-tight jacket connected to the pilot's oxygen reservoir. When exposed to sudden atmospheric decompression it automatically sucks in oxygen from the reservoir and inflates, thereby forcing some of the oxygen into the pilot's lungs.

As two of the doctors proved in the decompression chamber demonstration, this device provides a pilot who is suddenly deprived of his cockpit-canopy at 50,000 ft. with about 15 seconds of consciousness. This is generally long enough for him to make a controlled descent to a safer level.

Maintaining an adequate oxygen supply to the lungs is equally important at lower altitudes because a degree of anoxia which may not be severe enough to cause unconsciousness impairs the high levels of intelligence so that the pilot's judgment is affected, causing him to make gross and possibly fatal errors. The condition is especially dangerous because the sufferer from partial anoxia, like the alcoholic, may be quite unaware of his deficiency and feels particularly confident. The following incident which happened over Germany during the last war is typical of what can occur to the unsuspecting high-altitude flier. A pilot's breathing apparatus became disconnected at 18,000 ft. and he thereupon told the crew he was going to land. He lowered his undercarriage and tried to land on a cloudbank. When he failed to do this, he told the crew that they must be below ground-level, and that he was going to get out of the plane. The navigator, realising what must have happened, was just in time to stop him climbing out of the machine.

U.S. scientists are experimenting with an automatic device to warn a pilot when he is beginning to suffer from anoxia. It is a minute electro-encephalograph—a machine which makes a running record of the airman's 'brainwaves' as he flies. A metal strip fastened round his forehead picks up the minute electrical charges continually generated on the brain's surface; wires transmit them to a needle which traces them out as waves. When the brain gets short of oxygen the shape of these waves rapidly changes. In the experimental device such a change sounds a warning buzzer.

Drugs which might improve the oxygen-carrying content of the blood have been tried out at Farnborough, but were eventually abandoned. The most promising of these was the enzyme cytochrome which plays an essential part in cellular respiration. It was abandoned after test because results with it were not particularly successful, and the fact that it has to be *injected* reduces practicability.

A further high-altitude hazard which is not yet of operative importance but is being actively studied is visibility.

Pilots may soon be flying above those layers of the atmosphere where the incoming sunlight is scattered to form a blue sky. The backdrop of the sky will then appear dark blue, and they will be dependent for vision on light reflected from clouds or, on clear days, on light reflected from the earth's surface. At extreme altitudes visibility at noon in clear cloudless weather may be little better than on a bright moonlight night.

High speed in a straight line has no ill-effects itself on the human body, but rapid changes in speed or direction can be devastating. When a plane pulls out of a dive, for

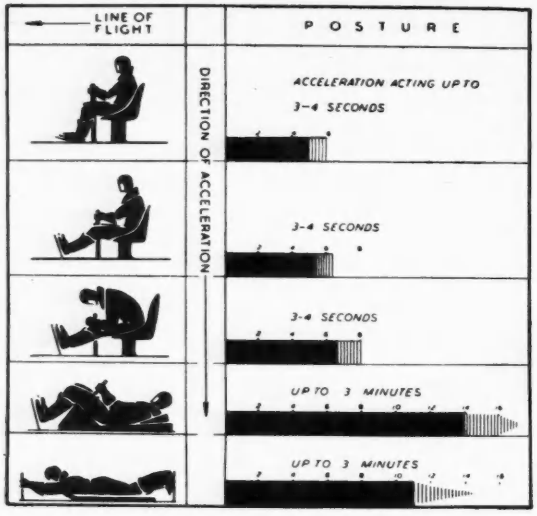


FIG. 4.—The effect of posture on the tolerance of acceleration. (From *Nature*.)

instance, the pilot experiences a centrifugal force which increases with the square of his speed. The tendency of this force is to push the pilot's body out through the floor of the aircraft, as the doctor-pilots discovered for themselves by acting as subject in the rear cockpits of aircraft fitted out as flying laboratories.

A turn at 300 m.p.h. along an arc of 1000 ft. radius produces a force of 6g—six times the force normally exerted by gravity. If the pilot's seat were fixed to a spring balance it would register six times his normal weight. In effect he would weigh about half a ton and his blood would become as heavy as molten iron.

The power of the heart is not, of course, increased so the head quickly becomes starved of blood and therefore of oxygen—while the legs become engorged.

The circulation of the retinas of the eyes is the first part to be noticeably affected and this leads immediately to the loss of vision which pilots call 'blacking-out'. If the velocity continues the whole blood supply to the brain fails and the pilot loses consciousness.

The R.A.F. Institution of Aviation Medicine is tackling these 'gravity' problems in several ways. The most direct is in the design of 'g suits', which are light-weight overalls fitted with automatic devices to restrain the flow of blood away from the head. These devices consist of a series of rubber bladders connected with a valve. The valve is so constructed that the bladders are automatically inflated by compressed air derived from the engine when the body is exposed to excessive gravitational forces. The bladders then press on the abdomen, thighs and other places where the blood would otherwise collect.

The latest 'g suits' enable a pilot to withstand an extra 2gs for about 15 seconds.

The second approach to the solution of gravitational problems is through the design of seating arrangements for aircrew. A pilot sitting chair-fashion can withstand 4gs for about four seconds without blacking out. If he adopts a hunched-up position with his legs sticking out more or less horizontally he can take more than 6gs for three or four seconds.

The physiological reason for this is that the distance through which the heart has to raise the heavy blood is much reduced. By putting the heart and head on the same level, i.e., by putting the pilot in a prone-lying or supine position, forces of more than 10gs can be tolerated for as long as three minutes.

Unfortunately these positions are extremely fatiguing and give the pilot little protection against the terrific decelerations experienced in crashes. (In the sitting position a pilot can tolerate up to 200gs for a fraction of a second.)

Nevertheless, the 'mattress' cockpit may become essential to supersonic flight. In the new American plane the Skystreak which is capable of speeds beyond 700 m.p.h., the pilot is in a semi-supine position with his heels almost level with his hips.

Work on the less spectacular but equally important 'g' problems of airsickness will shortly be intensified when the new human centrifuge building at Farnborough is completed.

This will be a circular laboratory 80 ft. in diameter, equipped with a centrally placed 2400 h.p. electric motor. Two arms each carrying a streamlined cabin on universal joints will extend from the motor. The subjects seated in the cabins will experience all the forces of high-speed aerial manœuvres as they are whirled round. Electronic equipment will record the effects of 'g' on heart-beat, brain-waves etc. Pilot reaction-time under gravity stress will be assessed.

With the advent of extremely rapid supersonic flight even travel at uniform velocities may be limited by physiological factors, at any rate as far as combat planes are concerned. Consider this example outlined by one of the R.A.F. physiologists:

Suppose two planes approach head-on at 1800 m.p.h. Coming out of cloud the pilots see each other when they are 8000 feet apart. Each pilot needs two-fifths of a second for the image of the oncoming plane to be relayed from his eyes to his brain. In that time the planes will get more than 2000 ft. closer. The brain takes about one second more to recognise the image as a plane by which time the machines will be little more than 600 feet apart. The pilots will need a further two-fifths of a second to make enough muscle movements to alter the controls. So before they can take evasive action their planes will collide.

Precautions against cold for air-crew have been necessary almost since flying began and the electrically heated suit is now commonplace. But with the greatly increased speeds made possible by jet-propulsion the heating problem in combat flying has been reversed. The friction of the plane with the air generates so much 'kinetic' heat that the pilot has to be refrigerated. (This kinetic heating may set an eventual limit of about 2500 m.p.h. on aircraft speeds. At greater speeds heating would probably be so intense that the aluminium alloys on which plane designers depend would lose half their structural strength.)

Refrigeration equipment is fitted in the latest jet fighters and in addition the R.A.F. medical researchers propose to pipe cool air direct to the flier's skin.

A ventilated suit for this purpose already exists having been originally designed for cooling fliers in tropical

FIG. 5.—Two R.A.F. doctors wearing oxygen waistcoats inside the decompression chamber described in the article.

countries. It consists of a thin overall with a series of short plastic pipes impinging on the skin at points where perspiration is greatest and supplying air at 85° F. Tests in the 'hot room' at Farnborough show that when the suit is switched on, the skin temperature falls three degrees in three minutes.

The value of this device for ordinary low-altitude flying in the tropics was proved by tests carried out recently at Khartoum. On a day when the ground temperature was 110° F. it was found that without using the suit a pilot's skin temperature went up seven degrees as soon as he climbed into a Vampire which had been standing in the sun.

The Institute is paying particular attention to what has become known as Arctic flying and a cold chamber in which the temperature can be dropped to –55° C. is in regular use. This work is particularly important for the welfare of the isolated and comfortless tail-gunner of bombers. In the latest heated flying suits a man can sit for three hours at –40° C. with little discomfort.

This type of climatic research will be intensified later this year when a new air-conditioned wind-tunnel is due to be completed. Weather conditions ranging from a 30 m.p.h. wind to hail, rain, and bright sunlight will be created in the tunnel whilst the doctors sit there testing new equipment.

A spectacular example of the Institute's work in connexion with escape equipment is the ejection-seat for jet aircrew.

It is extremely difficult and dangerous for a pilot to bale out unaided from a plane moving faster than 500 m.p.h. The R.A.F. physiologists therefore devised a seat which can be ejected explosively, thus shooting the man sitting in it well clear of the tail.

First step in the design of this equipment was to measure the jolt a man can stand at the base of his spine. A pilot's seat was fitted on the guide rails of a 110 feet high inclined tower. From tests carried out first with a dummy and later with volunteers it was found that an average man can tolerate an explosive force giving him an acceleration of 20g. provided this does not last longer than a fifth of a second. This enabled designers to build the now standard ejection-seat which blows the pilot clear after he has

jettisoned his cockpit. A barometrically operated fuse releases his parachute at a safe height.

For the faster planes of the future the detachment of the pilot's cabin as a pressurised capsule fitted with a parachute is envisaged.

The Institute is already equipped with an observation water-tank fitted with submerged windows for the testing of life-saving equipment. During my visit one of the doctors staged the first trial of a new 'Mae West' life-jacket, which a parachuting airman can inflate before he hits the water. The jacket—inflated by a tube of compressed carbon dioxide—is designed so that it does not interfere with the jettisoning of the parachute harness. With the old type life-jacket the 'drill' after baling out over the sea was to plunge into the water, release the parachute harness and then inflate the 'Mae West'.

Through the submerged windows of the observation tanks the doctors can see how well a new piece of equipment supports an unconscious man—usually one of their colleagues who has volunteered to be anaesthetised for the experiment.

In addition to all this activity there are, of course, many projects which cannot be described because of security restrictions.

Although the Institute of Aviation Medicine has the prefix 'R.A.F.' it also works in the interests of all flying. It is a pity, in my opinion, that the civil aircraft corporations do not pay more attention to the physiologists' findings.

For some years it has been clear that aircraft seats which face the tail must be considerably safer than forward-facing seats. Most aircrash deaths are due to the forward 'whip-action' of the body as the plane suddenly decelerates on striking the ground. Held by the safety-belt the body whips forwards sometimes breaking the neck or crashing the head against the seat in front. Many people burned to death in aircraft might have escaped had they not first been knocked unconscious in this way.

Crash tests carried out at Farnborough with a rocket-propelled dummy have shown that a passenger has a far better chance of surviving a crash if he is facing the tail since he is cushioned further into the seat instead of being whipped forward. The dummy—known as the Standard Man—had metal limbs and joints of approximately the same strength of the human body. Propped up in a seat it was fired on a rocket-propelled trolley at the speed of a crashing aircraft. Then it was jolted to a sudden stop. After each firing the dummy was examined for fractures. The tests showed that when the dummy faced backwards it escaped the forward whip action which causes most deaths in air crashes.

On this evidence the Air Ministry staged an experiment in which two Dakotas being used in the R.A.F.'s Britain-to-Germany ferry Service were fitted with backward-facing seats. Without being given the safety explanation passengers flying in them were asked their opinion of the seating arrangements. More than 80% said they preferred facing tailwards because it was more comfortable and gave them a better view from the windows.

The Air Ministry therefore decided that all the new planes of R.A.F. Transport Command—types like the Handley Page Hastings and Vickers Valetta should be fitted with tail-facing seats.

The wisdom of this decision was borne out by the first serious crash of a Handley Page Hastings which occurred near Benghazi last December. Four of the R.A.F. crew who were, of course, in forward-facing seats were killed. The 28 passengers in the backward-facing seats were all uninjured.

The civil airways corporations—BOAC and BEA—have refused to follow the Air Ministry's lead because they say that to make passengers crash-conscious is bad business psychology and they believe that too many passengers would object to sitting with their backs to the engines.

A CENTURY OF TECHNOLOGY

THIS Festival year, the centenary of the Great Exhibition year of 1851, provides a good vantage point from which to look back and assess the achievements of the last hundred years. It is no exaggeration to say that the visitors to the 1851 Exhibition would have been astounded could they have envisaged the amazingly rapid progress which science and its applications were to make before another century had passed. Even to us, who are accustomed to the rapidity with which technological development follows one discovery after another, a description of the major achievements of the last hundred years affords much that is surprising and many reasons for self-congratulation.

A review of progress in science and technology made during these years is given in *A Century of Technology* (Hutchinson's Scientific and Technical Publications, 346 pp., 15*s*.) edited by Dr. Percy Dunsheath and in a companion volume (due for immediate publication) *A Century of Science*, edited by Prof. Herbert Dingle.

The scope of *A Century of Technology* is very wide, embracing iron and steel, textiles, fuel and power, engineering, chemistry, agriculture, transport, telecommunications, printing and other branches of scientific application. There are nineteen chapters in all, each contributed by an expert in his particular field, and an abundance of good illustrations.

A typical contrast between 1851 and 1951 is found in a section dealing with glass, where it is said: "In 1851 glass was a costly material. Its main outlets were for drinking vessels and for window glass. Manufacturing methods were primitive. . . ." Imagine the effect the Crystal Palace with glass used on an architecturally grand scale must have had on the beholder! Now we have at our disposal glass in an infinity of varieties—heat-resisting glass, industrial glass piping, glass building blocks, foam glass, glass wool and fabric.

Some readers of the book may question whether 'progress' has always been maintained in a forward direction. The disappearance of the horse from the agricultural scene may have far-reaching repercussions, for example, not all of them of advantage. It is amusing to read that in 1851 there was a two-hour train service between London and Birmingham—a distance of 113 miles. In 1847 the distance of 112 miles from Templecombe to London was covered in 1 hour 44 minutes; the present-day travelling time for this journey is 2 hours 17 minutes.

Oceanography and Petroleum

PROF. C. M. YONGE, F.R.S.

THE Royal Research Ship *William Scoresby* has recently returned after a voyage of oceanographic investigation which has included physical, chemical and biological surveys of the waters of the Benguela Current off South-west Africa. One reason for these particular surveys was the light they might throw upon the vexed question of the origin of petroleum. The connexion between ocean movements and the deposition of oil is far from being obvious and is worthy of some discussion.

All living things accumulate within their bodies energy which comes initially from sunlight. It is received first by plants and from them may be passed to animals. In both it goes to the building up of elaborate organic compounds within which energy may thus be immobilised during much or all of the life of the organism. But after death bacteria break down these organic compounds into their simple inorganic constituents and turn to their own uses the energy so liberated. This is the normal sequence of events, energy temporarily locked away within plants and animals being, after their death, utilised and dissipated by bacteria.

Under certain circumstances, however, bacterial decomposition is incomplete and a significant proportion of the organic matter persists and the energy accumulated within this retained. Deposits of coal and of oil, still our major sources of energy, were both so formed; they represent the results of incomplete decomposition of the bodies of plants and animals. Coal was formed on land, more precisely in swamps, and consists of the remains of the great forests of the carboniferous period. There is no mystery about the origin of coal but oil is another matter. This was certainly accumulated on the obscurity of the ocean floor and for that reason its origin still remains a matter of consideraole speculation.

Certain circumstances would, however, seem to be necessary for the initial mass accumulation of organic remains. There must have been great local abundance of marine life which was subject to periodic destruction while conditions on the bed of the ocean must have been such as to prevent the complete bacterial decomposition of the organic matter which collected there. The initial problem is thus one of productivity and this, in the sea, is dependent on the same factors of daylight and of nutrient salts or fertilisers, notably nitrates and phosphates, as it is on land. The great flowerings of marine plant life, of the microscopic diatoms and dinoflagellates which represent the true meadows of the sea, can occur only in illuminated surface waters when these are also enriched by nutrient salts. The population of animals, no matter whether these be large or small, or whether they dwell in the surface waters, in middle depths or upon, or even within, the bottom deposits, is ultimately entirely controlled by the abundance of this plant life.

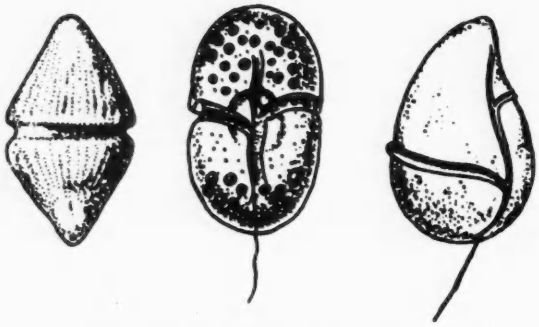
The deep and dark layers of sea water represent an enormous reservoir of nutrient nitrates and phosphates. These have been liberated by the action of bacteria from the dead bodies of animals and plants most of which have fallen to the bottom from upper levels. But these essential salts can only be utilised again if and when they come into the illuminated surface waters where they can be incorporated by plants into complex protein molecules. In polar seas where deep and surface waters mix freely there is immense productivity, supplying the needs of schools of whales which represent one of our major sources of fats, but this is confined to summer months when alone there is adequate light.

In temperate and tropic seas such free mingling of waters is largely prevented by the formation of a warm surface layer which effectively floats on the surface of the cold and heavier water below and from which it is separated by the invisible barrier of what is known as a 'discontinuity layer' in which there is a very sudden drop in temperature. Around our own coasts surface temperatures fall in winter and then the waters become mixed from top to bottom with consequent replenishment of the surface for the needs of the coming spring and summer. Hence productivity in these latitudes is highest in spring to decline, after depletion of nutrient salts, in the summer.

Only where both light and salts are always adequate can productivity be continuous. Such conditions do prevail, mainly in warm temperate regions, where there is continuous upward flow of deep water which prevents the formation of a distinct surface layer. Where such currents 'upwell' the surface waters are unusually cold but are rich in nutrient salts. Their productivity can be enormous. The classic case is that of the Humboldt Current off the coast of Chile and Peru, where these salts nourish a rich microscopic plant life on which feed vast shoals of anchovies which in turn provide food for flocks of pelicans, cormorants and boobies. These breed on rainless islands where their droppings accumulate, forming guano in which the nutrient salts, coming initially from deep Antarctic waters, become available in the most concentrated of all natural fertilisers.

Such great productivity, the result of upward flow of deep water, may well be the first condition of eventual oil deposition. Next comes the question of mass destruction. The sea is a more stable medium than the land, less extreme in temperature and changing very slowly. And life on land is the more subject to wide fluctuations, dramatic periodic increase in numbers, notably of rodents and insects, being followed by mass destruction. Marine populations certainly vary, the yield of the herring fishery indicates this, but in our own seas there is seldom evidence of anything approaching mass mortality.

There are, however, recorded instances in other seas of catastrophic destruction of fish and other marine animals. A recent and particularly well-documented instance will suffice for illustration. It occurred off the west coast of Florida between November 1946 and August 1947, when millions of fish died. Their bodies covered the surface of the sea and were thrown in piled up masses along the beaches. During this period the surface of the sea was streaked with reddish-brown patches. Such 'red water' has been observed by many, one of the first being Charles



Gymnodinium spp. showing equatorial and longitudinal grooves, each containing a flagellum, characteristic of the Dinoflagellata. × 800. (After Schutt.)

Darwin when off the coast of Chile in H.M.S. *Beagle*. It is due to a vast increase, known as a 'blooming', of certain micro-organisms, in this instance the minute red dinoflagellate, *Gymnodinium*.

There seems no doubt that, at any rate when they occur in such great concentrations, these organisms are poisonous to fish. Blooming of a related dinoflagellate, *Gonyaulax*, appears to be similarly responsible for the toxicity to man, at these periods, of Californian mussels which feed upon them. It is the conditions which permit of this blooming which are somewhat obscure. But most probably these are brought about when there is an enrichment of surface waters from below but at the same time temperatures are unusually high. Then the possibilities of increase represented by the nutrient salts are rapidly realised. As often happens under such circumstances, there may be a dramatic increase of one particular species which, as in the case outlined, proves fatal to many others.

Mass destruction may thus be the fate of marine animals, and there are many records of this from the Atlantic, Pacific and Indian Oceans. But for similar events in the past to represent a stage in the accumulation of organic matter later to form oil, bacterial decomposition must have been arrested as it was in the swamps during the early stages of the formation of coal. This implies absence of oxygen from the sea bottom and the consequent restriction of bacteria to purely anaerobic forms. Such conditions were indeed thought to exist by Edward Forbes, the leading oceanographer of the first half of the nineteenth century. He knew that marine life diminished with increasing depth and postulated its final disappearance in a profound azoic zone. But we now know that life exists at all depths due to the presence of oxygen carried in deep ocean currents. Only where such deep circulation is absent, notably in the Black Sea and in marine pools isolated behind terminal moraines at the head of Norwegian fjords, is the bottom devoid of animal life because oxygen is replaced by hydrogen sulphide produced by anaerobic bacteria.

But the suggestion is that essentially similar conditions may be locally produced following a rain of bodies from the surface due to mass mortality. This destruction would also be expected to overwhelm the worms, molluscs, crabs and the like which scavenge the bottom. The end result might well be such an accumulation of organic debris that aerobic bacteria use up all oxygen and remain unable to cope with the supply. Much of this could only be partially broken down by anaerobic bacteria and in this form becomes buried under the bottom mud. The fossil fishes which occur in rich abundance within shale deposits are thought to have accumulated under such conditions.

The coast of South-west Africa, to return to our starting point, is a region of upwelling water and one, moreover, where mass mortality does seem to be of frequent occurrence. Offshore also there is evidence of the presence of an 'azoic zone' where the bottom is covered with sterile greenish mud that smells strongly of sulphuretted hydrogen. It is by no means an unreasonable assumption that under very similar conditions there may slowly and over vast periods of time have accumulated the source of the oil that man is now so rapidly squandering. The results of the surveys carried out by the *William Scoresby* cannot but aid in revealing the elements of truth contained in the speculations I have briefly outlined.

A Safe Systemic Insecticide

A SYSTEMIC INSECTICIDE safe enough to be used by the gardener is announced by Pest Control Ltd., of Bourn, Cambridge. It is called 'Isopestox'. The chemical name of this compound is bis isopropylaminofluorophosphine oxide. The pure chemical is a solid, melting at 60°C. and is very hygroscopic; it is made up into a solution containing 50% Isopestox. It is not volatile, does not smell, and is not corrosive. In the commercial formulation a warning colour, methyl violet, is added.

Its oral toxicity to rabbits and guinea pigs is low; it is 26 times *less* toxic than Parathion, 9 times less toxic than nicotine, and little more than twice as toxic as DDT.

It is recommended for late outbreaks of aphids or red spider on hops, and for treatment of cabbage aphis on Brussels sprouts later in the year. It is an excellent systemic insecticide for the amateur gardener and the glasshouse horticulturist, and can be used on vegetables such as spinach or lettuce where Pestox 3 is not recommended. It should greatly facilitate lettuce growing, because the lettuce aphids have been largely inaccessible by ordinary insecticides and can only be reached by a systemic insecticide once the heads of the lettuce have formed. Isopestox thus seems to fill a useful gap in the armoury against pests.

Isopestox was discovered by Dr. G. S. Hartley. It is the first systemic which Pest Control Ltd. has produced where the chemist had certain physical and chemical characters of the finished molecule in mind, and put it together accordingly. It is what chemists call "a true tailor-made molecule".

Samples for research and test purposes and commercial quantities will be available in May.

FIG. 1.—Corkwood tree (*Hakea*). There are 100 species of corkwood trees which are adapted to existence under extremely dry conditions. (Photo by Charles P. Mountford from *Brown Men and Red Sand*: see this month's 'Bookshelf'.)

The Flora of Australia

D. A. HERBERT, D.Sc.

Professor of Botany, University of Queensland.

THOUGH the western and northern coasts of Australia had been charted during the seventeenth century, it was not until Captain James Cook's great voyage of 1768–71 that there was any real knowledge of the plants of the continent.* William Dampier, the English buccaneer, had, it is true, paid two visits to the north-west coast towards the end of the seventeenth century and had made some observations on the unique nature of the plants he saw, and had brought back a few dried specimens which are still preserved in the Fitzwilliam Museum at Cambridge.

With Cook on the *Endeavour*, however, were Sir Joseph Banks and Dr. Daniel Carl Solander, both keenly interested in the vegetation of the new land, and it is due to their energetic collecting that hundreds of new species became known to European scientists. Their work commenced at Botany Bay on April 30, 1770. The original name of Stingray Harbour was changed because of the number of plants collected by the botanists on their week's stay. For four months the *Endeavour* followed the eastern coast northwards, and the collections included both temperate and tropical plants. They aroused the greatest interest amongst European botanists and gardeners for a diversity of reasons. The new plants were an excellent test for the Linnæan system of classification, which had been based on other floras; there was a possibility that they might not fit at all. Fantastic stories had already been woven round the country and its inhabitants; it was in Australia that Dean Swift had placed the land of Lilliput. To the systematic botanists the wealth of new species opened up a tremendous field. For the gardens there were new and beautiful plants to be cultivated and improved. Soon after the settlement of the country, collectors were actively sending back seeds and plants. In 1802 the French botanist, Leschenault de la Tour, wrote that Australian plants "remarkable for the elegance of their flowers" were growing well in the gardens of Malmaison and Paris.

During the nineteenth century collections of New Holland plants, as they were called, were eagerly sought in Europe, and their cultivation became something of a craze. Many, no doubt, were grown for their novelty—for example *Cephalotus*, the Western Australian pitcher plant, with pitchers like those of *Nepenthes* and *Sarracenia*, yet not related to either of those plants; and *Stylidium*

* Cook's voyage had a primarily scientific objective—it was very definitely a scientific expedition, sent out to get an accurate observation of the transit of Venus in 1769. Captain Cook and the astronomer, Charles Green, were appointed observers for the Royal Society. It was the Royal Society which arranged with the Admiralty for Banks and his suite to accompany the expedition; he took with him his friend Dr. Solander (a Swedish naturalist who had come to England at Linnæus's suggestion), four artists, and four servants.

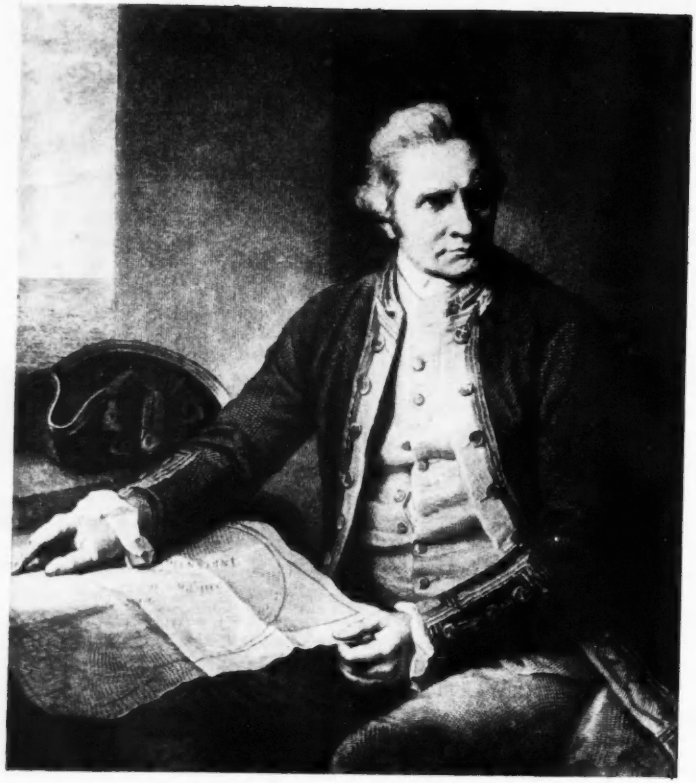
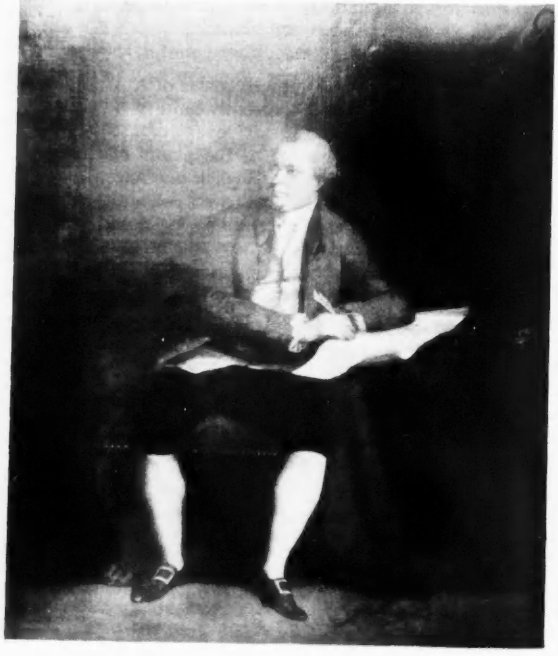


FIG. 2.—Captain James Cook.

FIG. 3. (*Below left*)—Joseph Banks (Mezzotint after Sir Joshua Reynolds *c.*1774).
FIG. 4. (*Below right*)—Dr. D. C. Solander, botanist to Cook's first Australasia voyage.



(otherwise known as *Candollea*), the trigger plant, but many others became popular favourites for sheer merit as ornamental plants. Some, such as the Blue Lace Flower (*Didiscus coeruleus*), were destined to return to their original home years afterwards in greatly improved form and become standard garden flowers.

Curiously enough, very few good food plants have ever been found amongst the Australian native flora. The Australian aboriginals were hunters and grew nothing. Though there are many plants with possibilities, they had never been used except in the wild state and no attempt had been made to improve them. There are several species of wild raspberry, yams, various Eugenias (this is the genus to which belong the Malay apple and spice cloves) that are used in the bush for making jelly, and many salad plants including *Tetragonia expansa*, generally called New Zealand spinach. One tree, the Queensland nut (*Macadamia ternifolia*), is grown commercially in Australia, Hawaii and elsewhere, and bears one of the finest of edible nuts; a minor defect, the hardness of the shell, has been overcome by the breeding of thin-shelled varieties. Australia's great contributions have been in timber trees (of which the Eucalypts or gum-trees are outstanding), tanbarks, plants with essential oils (and here *Eucalyptus* is again important), some medicinal plants, notably species of *Duboisia*, and a tremendous array of ornamentals.

The Vegetation

In a continent of nearly three million square miles, which includes jungles and deserts, mountains and plains, tropical lowlands and alpine uplands, there must of necessity be a great variation in the flora. The broad general picture is that of a great arid stretch of desert, steppe and scrub in the centre (where the annual rainfall is 15 inches or less) and, surrounding that, concentric belts where the increasing rainfall towards the coast supports savannah woodland, Eucalyptus forests and finally—in scattered areas of high rainfall—the rain forests.

But this is only a general picture. Rain forests are of very limited occurrence in Tasmania and parts of the eastern coast; they are entirely absent in South Australia, Western Australia and the Northern Territory. The arid or steppe country reaches the coast along the Great Australian Bight and along the north-west coast. The coastal forests are far from being a continuous rim round the sparsely populated arid interior. They really form an interrupted marginal band, which is about 200 miles wide, with two great gaps isolating the south-western corner of the continent from the north and east.

The Eucalyptus Forests

The Eucalyptus forests are to the visitor the most characteristic feature of the Australian landscape, because they happen to be dominant in the densely populated parts of the continent. There are approximately five hundred species of *Eucalyptus*, and though they differ in stature, bark characters, and in the situations in which they can grow, they have so much in common that the bushland presents a curiously uniform appearance wherever it occurs, from the tropics to Tasmania. The trees have none of the mellow softness of the oaks and elms of other lands. They are evergreen, and have the same appearance in summer and winter, in deluge and in drought. They have a beauty all their own; with some species it arises from the delicate tints that dapple the smooth white bark, with others from the bright red of the young leaves, and with others again from the brilliance of the scarlet flowers.

The Eucalypts have been widely used abroad as ornamental, shelter and timber trees, and over fifty different kinds are in common cultivation. Most of them have white or cream-coloured flowers, but there are some magnificent red- and pink-flowering species. *E. ficifolia*, the red-flowering gum of Western Australia, is one of the most beautiful flowering trees in cultivation, with its immense heads of blossom standing out from the foliage. The orange-scarlet *E. torquata*, the scarlet *E. tetraptera*, the pink *E. leucoxylin rosea*, the bright yellow *E. grossa*, *E. platypus* and *E. stricklandi* are amongst the many grown for their showy flowers. *E. globulus* (the Tasmanian Blue Gum) and *E. cladocalyx* (the Sugar Gum of South Australia) are amongst the fine avenue trees in the genus. The ornamental types are too numerous to mention, but there are species suitable for almost any climate, ranging as they do from the snow gums of the cold mountain tops to the gums of the tropical coast of Queensland and the Northern Territory.

Practically all of the Eucalypts contain leaf oils that vary in composition and are characteristic of each species. A few have lemon-scented oils—notably *E. citriodora*, the lemon-scented gum of Queensland, the leaves of which are exploited for citronella. Some of the Eucalypts attain gigantic size. *Eucalyptus regnans*, the Mountain Ash of South-eastern Australia, is second only in size to the Sequoias of California. Occasional trees attain more than 300 feet in height. Almost as huge are the Karri trees (*E. diversicolor*) of Western Australia.

Acacias

The Acacias or Wattles come next to the Eucalypts in importance amongst the trees of the coastal strip, but whereas the Eucalypts are, with one or two exceptions that have invaded the north, characteristically Australian, only about half of the eight hundred Acacias of the world are native to this continent. They are the glory of the bush in spring, when their golden blossom brightens the landscape and scents the air. Special excursions are run in the Victorian spring, to see the Silver Wattle (*Acacia dealbata*) lining the creeks with its masses of golden blossom. This is the species which is sold in England as *mimosa*. (The flowers of *A. dealbata* familar to British readers are usually grown in the South of France.) The early settlers in Australia used this common name for some of the species of *Acacia* (which is closely related to *Mimosa*),* but it now persists only in mutilated form, some of the thorny species being known as 'Prickly Moses'. The name in more common use is 'Wattle', and refers to the early use of the branches, which were sealed with wet clay, in the building of 'wattle-and-daub' huts. *A. acuminata*—the Raspberry Jam tree, so called from the scent of its wood—is a fine flowering species from the Western Australian wheat belt.

* *Acacia* and *Mimosa* belong to a division (*Mimosoideæ*), of the Leguminosæ—the pea family, the second largest family of flowering plants.

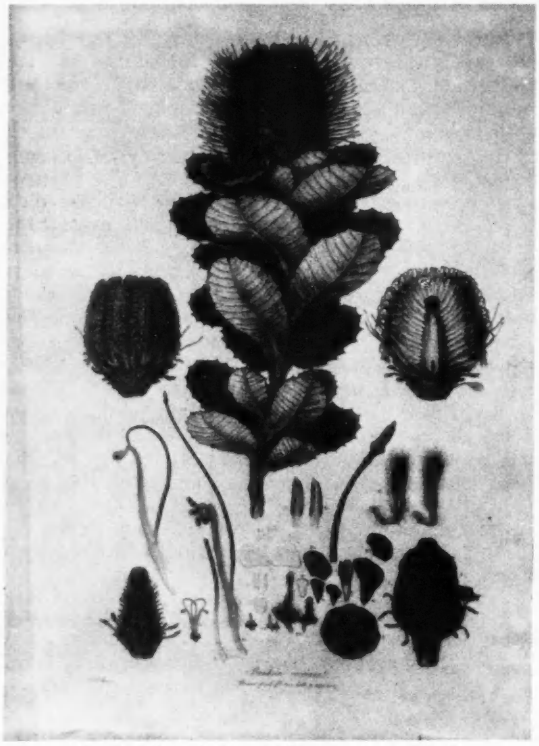


FIG. 5.—Banks's flower (*Banksia coccinea*), with the characteristic pineapple-like inflorescence. There are about 50 species of Banksia.

Acacia pycrantha (the Golden Wattle), *A. baileyana* (the Cootamundra Wattle), *A. podalyriaefolia* (the Mount Morgan Wattle from Queensland) and *A. spectabilis* (the Mudgee Wattle) are amongst the garden favourites.

The complete list of cultivated species, however, is a very long one, and includes dwarf shrubs such as *A. buxifolia* about three feet in height, and great trees such as *A. elata*, which may reach eighty feet. Apart from their ornamental value the Acacias are important in other directions. *A. decurrens mollis*, one of the black wattles, is now widely planted, especially in South Africa, as a tanbark tree. Others yield valuable timbers; the blackwood (*A. melanoxylon*) is of special importance for its fine cabinet wood. In the arid parts of Australia the wattles still thrive where the Eucalypts fail. Mulga, myall, dead finish and gidgee are some of the dry-country acacias. Mulga (*A. aneura*) forms tremendous stretches of scrub in the interior. It is a small tree particularly useful in times of drought; the branches are lopped and the foliage is eaten by sheep and cattle after the herbage has disappeared.

Tea-Trees and Bottlebrushes

The Australian bush is particularly rich in members of the Myrtle family (*Myrtaceae*). The Eucalyptus trees belong here, but tea-trees (*Leptospermum*, *Melaleuca* and *Kunzea*) and the Bottlebrushes (*Callistemon*), which are usually shrubs or small trees, are often so showy and numerous that they play a major part in the spring display of flowers, especially on our sandy heaths.

The *Leptospermums* are for the most part shrubs and small trees bearing masses of white bloom in spring, though there are few times in the year when some species are not in flower. The name 'tea-tree' refers to the use of the leaves for an anti-scorbutic infusion by Captain Cook*; it is now in common use for any of the shrubs that look like *Leptospermum*. It is safe to say that they are never used as a tea substitute. Apart from minor uses of their timber, the main value of *Leptospermum* species is as ornamentals, and some very fine horticultural tea-trees are now in cultivation. They are for the most part double-flowered, or coloured derivatives of *Leptospermum scoparium*. *L. rotundifolium*, with large flowers of delicate pink reminiscent of peach blossom, is one of the gems of the bush. The *Melaleucas* are rather different in that their flowers are borne in cylindrical spikes, the projecting stamens giving them the appearance of bottle brushes. One of the finest is the mauve *M. nesophila* from Western Australia. In the tropical north the paper-bark tea-tree (*M. leucodendron*) is one of the commonest trees of the swampy country; it is a curious tree with its swaddling of white sheets of bark like blotting-paper. It is a very variable tree; it often has pendulous branches, and some of its pink flowering forms are of great beauty.

For brilliance of flowers, however, few of the tea-trees can approach the *Callistemons* with their rich red cylinders of tightly packed flowers. *Callistemon salignus* lines the Queensland creeks, and in spring its pendulous branches are a cascade of crimson.

Banks's Flower

The family Proteaceae is a very important one in Australia, because of the extraordinary diversity of its members, a characteristic that gives it its name, the Greek soothsayer Proteus being noted for his ability to change his shape to suit his immediate objectives. *Banksia*, *Grevillea* and *Dryandra* are well-known members. *Banksia*, named after Sir Joseph Banks, is a genus of trees with stout spikes of flowers, often brilliantly coloured and perfectly erect, giving the trees the appearance of giant candelabra. *B. collina* and *B. ericifolia* are shrubby species of horticultural importance because of their smaller size. Most of the species, however, are robust and grotesque trees; they are a magnificent sight in the bush, but prove somewhat incongruous amongst more shapely trees of a formal garden. (The name 'Banksia' was suggested by the great

* Cook's first voyage to Australasia was truly remarkable from the medical point of view; only one man died of sickness during the whole of the three years, and Cook kept scurvy at bay dietetically, whereas most contemporary commanders were suffering serious losses through this vitamin-deficiency disease. For this achievement the Royal Society awarded Cook the Copley Medal; conferring this award on Cook, the Royal Society's president said, "If Rome decreed the Civic Crown to him who saved the life of a single citizen, what wreaths are due to that man who, having himself saved many, perpetuates in your *Transactions* the means by which Britain may now, on the most distant voyages, preserve numbers of her intrepid sons, her mariners." It remained for James Lind, the British physician, who accompanied Cook on his second voyage to Australia and who afterwards became the King's Physician, to spread this dietetic knowledge throughout the British Navy; scurvy, the great scourge of the sea, was defeated by plant juices containing, as we now know, vitamin C.

FIG. 6. Typical vegetation along an Australian river, Eucalyptuses dominating the upper layer, with a thicket of acacias, tea-trees, and other small trees below.

FIG. 7.—Karri (*Eucalyptus diversicolor*). A gum tree of South-western Australia which attains a height well over 200 feet.

FIG. 8.—The Raspberry Jam Tree (*Acacia acuminata*) of the Western Australian wheat belt. The common name refers to the scent of the wood.

FIG. 9.—A typical wattle (*Acacia dealbata*).

Swedish botanist Linnæus as being a suitable name for the continent of Australia.)

More amenable to ordinary garden culture are many of the species of *Grevillea*, such as *G. punicea*, with its rich red flowers like cats' claws, and *G. rosmarinifolia*, which has pink flowers. From Queensland comes that fine crimson-flowering small tree *G. banksii fosterii*. An important timber tree, *G. robusta*, the Silky Oak, is a blaze of orange in early summer. In Brisbane it is commonly planted with the blue-flowering Brazilian tree, the Jacaranda, with which it makes a vivid contrast. Its greatest value, however, lies in its timber, and it is planted on a considerable scale in Queensland for forestry purposes. *Hakea* and *Dryandra* are two shrubby genera that provided many "New Holland" plants for European gardens in the nineteenth century; one of those that has maintained its popularity is *Hakea eucalyptifolia*, the crimson pincushion flower.

The family Ericaceae, to which the true heaths (heather and ling) belong, is not well represented in Australia. Perhaps the best is the only species of *Rhododendron* found in the continent, the red-flowered *R. lochiae* which occurs on a few mountains in North Queensland. There is, however, a great development of the Australian family of heaths, the Epacridaceae. Some of them are of exceptional beauty, but they are difficult of cultivation. *Leucopogon virgatus*, when covered with its small white flowers, looks like a heap of glistening salt. The best of the Australian heaths are members of the genus *Epacris*. *E. impressa*, the common species of south-eastern Australia, has spikes of flowers like those of an *Erica*, in a charming range of tints from white and pink to red.

The various species of *Boronia* are small shrubs commonly, but not exclusively, found in heathlands. There are over seventy species, mostly with pink blossom, and they are amongst the most popular of the Australian wild flowers. The brown Boronia, *B. megastigma*, which grows in Western Australia, has a delightful scent and is widely cultivated for that reason.

There are over six hundred members of the Daisy family or Compositae in Australia. Perhaps the most interesting are the everlastings or immortelles whose dry flowers retain their freshness for months after they are picked. Most of them are golden yellow but there are white, pink, red and purple species. In the arid centre of Australia it is no uncommon sight to see thousands of acres covered with these plants in full bloom. Then comes a shower and in a few minutes the colour has gone; the moistened flowers have closed. The glory has departed until the flowers dry and open again.

Australian Legumes

Members of the pea family (Leguminoseæ) are exceptionally common. There are trees (such as the brilliant coral tree, *Erythrina*, of the northern parts), climbers (e.g. the beautiful purple *Hardenbergia* and the red *Kennedya*) and a whole host of shrubs, mostly with yellow or red flowers. These shrubs include *Pultenæa*, *Dilwynnia*, *Aotus* and *Daviesia*, and—unfortunately—the very poisonous members of the genera *Oxylobium* and *Gastrolobium*. It is a curious fact that marsupials eat these poisonous species without apparent effect, but they are deadly to the introduced domestic animals from abroad.

Many of the legumes, including acacias, commonly grow abundantly in areas that have been swept by bush fires. Their wax-coated seeds normally germinate with some difficulty, but the charring of the seed-coats and the melting of the waxy coat facilitate the entry of water and after the first rains following a fire the plants come up in enormous numbers.* This treatment is imitated by gardeners by the removal of part of the seed-coat or by hot-water treatment before planting, and is the regular procedure in raising wattles and that magnificent herbaceous species the Sturt Desert Pea (*Clianthus speciosus*). The Sturt Pea has brilliant scarlet flowers with a shining black eye. Though it naturally grows in very dry country it is very amenable to cultivation, even in glasshouses. The Darling Pea (*Swainsona galegifolia*) with large red pea-flowers, was one of the earliest of Australian plants to be cultivated and is now regarded as an old-time garden plant. In its native habitat it is not at all highly regarded, because it is poisonous to stock.

The Australian orchids fall into two types, the ground orchids and the epiphytes that grow in the aerial gardens of the jungle tree tops. Though the ground orchids lack the size of the epiphytes, their forms and colouring are such that they rank with the wattles and Boronias in the affections of Australians. Pink fingers (*Caladenia carnea*) and the blue *Glossodia minor* in places carpet the ground in

* The advantage given to these plants by the charring of the soil is reminiscent of the way *Epilobium* sweeps into burnt areas in Britain (e.g. the bomb sites in London).

thousands. One common orchid, *Dipodium punctatum*, is leafless and obtains its nourishment from the soil through the help of a fungus. Some years ago a collector in digging up a plant of *Dipodium* in New South Wales discovered a subterranean orchid to which the name *Cryptanthemis slateri* has been given. This was the second subterranean orchid to be discovered in Australia, the other being *Rhizanthella gardneri*, which was ploughed up in Western Australia.

Two Australian ground orchids, *Phaius tankervilleæ* and *Calanthe veratrifolia*, are well-known in cultivation, but the principal horticultural species are rain-forest epiphytes, mostly from coastal Queensland. The principal genus is *Dendrobium*. *D. speciosum*, the King Orchid, may form plants large enough to fill a dray and in spring is covered with plumes of cream flower sprays. *D. undulatum*, the Golden Orchid, is found on the branches of trees and on rocks, often right on the shore. Curious forms of fleshy leaf give other species such common names as Pencil orchid, Tongue orchid, Wheat orchid or Cucumber orchid. Probably the finest of all is the mauve Cooktown orchid of North Queensland, *Dendrobium bigibbum*, which exists in several varieties, and which has been used very considerably in hybridisation. The magnificent white butterfly orchid, *Phalaenopsis rosenstromii*, is comparatively rare, as are the two Australian species of *Vanda*—*V. suavis* (which has a natural range beyond Australia) and the recently discovered *V. whiteana* from North Queensland.

FIG. 10.—The Cooktown Orchid (*Dendrobium bigibbum* var. *phalaenopsis*). A cultivated orchid from North Queensland.

Mistletoes (*Viscum*) are of common occurrence, but they exhibit two points of outstanding interest. The first is the fact that several species of *Viscum* parasitise other mistletoes; the second is that Western Australia possesses a tree mistletoe, *Nuytsia floribunda*, which parasitises the roots of other plants. This common western species is a glorious mass of orange flowers in midsummer and is usually known as the 'Christmas Tree'.

Insectivorous Plants

Insectivorous plants are numerous. Besides the well-known *Drosera* (the Sundew), of which there are over sixty species in Australia, there is *Byblis gigantea*, of curiously similar habit with its sticky glands. There are, too, numerous species of *Utricularia*, the bladderwort, and the related *Polypompholyx* which trap small victims in their ingeniously constructed bladders.

Round Albany in Western Australia is the curious endemic pitcher plant *Cephalotus follicularis*; its pitchers, about the size of a plum, are water traps for visiting insects which are drowned and finally absorbed. In North Queensland there is one species of *Nepenthes*, the common pitcher plant of hot houses.

The Relationships of the Australian Flora

The principal plant families of other parts of the world are also for the most part the principal families of Australia, but long isolation, past changes of climate and geography, and peculiarities of the present climate, have evolved a flora that is characteristic of the continent. What is perhaps the essentially Australian flora is that of the areas with a pronounced dry season. It is here that we find the Eucalypts, Banksias, Acacias and Boronias. There are no countries near at hand with climates to which these can spread or from which other types may migrate. In the rain forests of Queensland, however, we have a very strong resemblance to the plants of New Guinea and other wet regions even farther afield. The mangrove forests of the tidal flats are essentially similar to those of the old-world tropics. The alpine plants of the mountain tops of Victoria and Tasmania are growing in climates that are repeated in New Zealand and in the mountains of New Guinea, and there are very strong similarities. There are resemblances, though not quite so strong, to some of the African plants. We no longer regard these as being necessarily invaders that have obtained a precarious foothold in Australia, but rather as part of a widespread mixture of plants sorted out by climate into their own niches, and modified in the course of the ages to form the Australian aspect of the old-world vegetation.

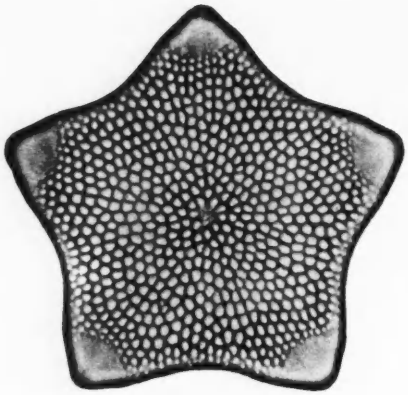


FIG. 1 (*left*).—The diatom *Triceratium cyclamen*. Distance between the angles is 115 microns. (1000 microns = 1 millimetre).

FIG. 2 (*right*).—*Arachnoidiscus sendaicus*. Its diameter is 135 microns.

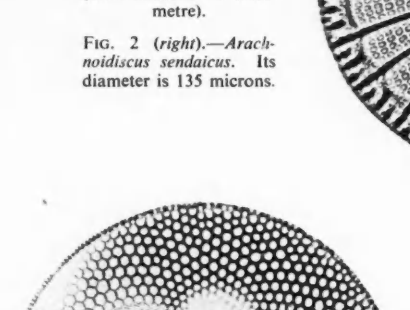


FIG. 4 (*above*) *Coscinodiscus excavatus*. Diameter, 195 microns.

FIG. 5 (*below*).—*Triceratium schmidtii*. Diameter, 250 microns (about a hundredth of an inch).

FIG. 3.—*Asterolampra vulgaris*, with a diameter of 90 microns.

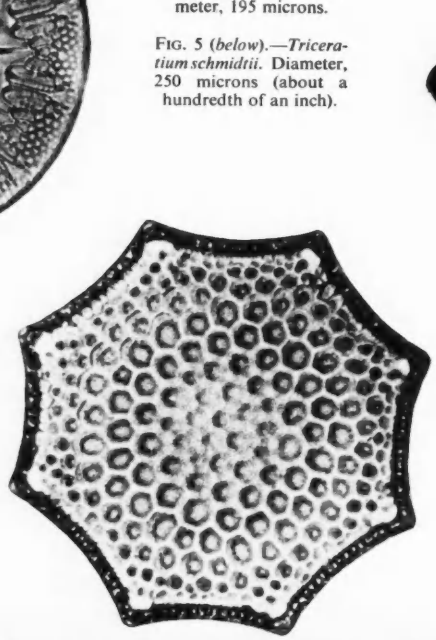


FIG. 6.—*Entogonia jeremiana*. Distance between the angles, 65 microns.

PHOTOMICROGRAPHS
By Dr. M. M. FRIEDMAN

Diatoms: Their Beauty and Uses

HENRY WELSH, F.R.A.S.

WHAT are diatoms? They are unicellular (single-celled) plants of incredible beauty and great diversity of form, that occur in vast numbers in both fresh and salt water. Each diatom is enclosed in a wall consisting of two more or less equal *valves*, which are joined together by two connecting bands; the valves fit together in the same sort of way as do the two halves of a pill-box.

The valves are formed of silica secreted by the diatom. So much for the skeleton of these organisms, which being of silica is resistant to decay and retains its shape after the death of the plant. Diatoms contain chlorophyll, but this may be overshadowed by a brownish pigment, so that the organisms may appear greenish-yellow or chocolate-brown.

The first diatoms were observed by Leeuwenhoek, the first of the great 'microbe hunters', at the very beginning of the eighteenth century. Because of their size the study of diatoms has been intimately tied to the development of the microscope. Actually in the long history of the perfecting of the microscope diatoms have been of service, for owing to the fineness of some of the markings on them they made superlative text objects. Thus the French microscopist, Pelletan, claimed that diatoms have contributed more to optical improvements in microscopes during the past 100 years than all the rest of created nature.

Most diatoms are exceedingly small, and invisible to the unaided eye. Comparatively few of them are as big as one hundredth of an inch in diameter, i.e. as large as a printed full stop. One gets some idea of the minuteness of these lovely organisms from the estimate of the well-known diatomist who has calculated that all the diatomists in the world had not yet examined under the microscope a cubic foot of diatom material. Yet the artistic beauty of these minute organisms is remarkable. It has, however, scarcely begun to be exploited, though it is no exaggeration to say that the filigree work on some diatoms would put even a Benvenuto Cellini or a Fabergé to shame were he to attempt in gold and silver and the arrangement of precious stones the exquisite patterning of many diatoms.

Most species of diatoms are found in water: in the seas and oceans, in rivers, lakes, ponds and ditches. But they also grow in damp places such as peat bogs and marshes, and in gutters, drain pipes and water butts, and on piles, mill wheels, and so on. Their presence in vast numbers in guano, which is well-known as a valuable fertiliser, is explained by the fact that the sea-birds eat the fishes which eat the shrimps which eat the diatoms!

There are some species which are distinctly marine, others that prefer brackish water, and yet others which can live only in fresh water. But there is inevitably a certain amount of commingling of species at the mouths of rivers, where we find fresh-water forms brought down by the rivers mingling with the brackish forms of the estuary and those brought in from the seas by the tides.

Diatoms are found from the tropics to the poles, and even at great altitudes on mountains. They thrive exceedingly in the cold waters of the polar seas and polar explorers have found them on ice-floes and icebergs.

They have also been found in the hot springs of Nevada and Colorado where they flourish in a temperature of 160° F. to 175° F. It will thus be seen that they are ubiquitous, as well as hardy and adaptable. They do not grow in the great depths of the ocean where light cannot penetrate, nor in stagnant waters. Diatoms assist in purifying the water in which they live by liberating free oxygen and an abundance of diatoms in fresh water is usually a sign that it is pure enough to drink.

The diatomist is equally well served by fossil deposits which are found in various parts of the world. In North America vast strata of diatoms, representing the skeletons of millions upon millions of these organisms which settled to the bottom of prehistoric seas and lakes, are found in Virginia and Maryland on the Atlantic side, and in California on the Pacific coast. The city of Richmond, Virginia is built on a layer of fossil diatoms 15 ft. in thickness. The diatoms found in this and other fossil deposits are often of species that have become extinct, though there are a good many species flourishing today that first emerged millions of years ago. Some diatoms have altered but slightly in the course of time, others have remained unchanged.

There are numerous industrial uses for diatomaceous earths. For polishing purposes, diatom skeletons are superior to powders composed of amorphous silica; and diatomaceous earth is mixed into mineral pastes, soaps, tooth pastes, and polishes for wood, shell or metal. Diatomaceous earth is also used in the manufacture of porcelain, and certain cements and artificial stones.

Diatomaceous earth was known to the Greeks and Romans; the Emperor Justinian, for example, instructed his architects to use it in the construction of the dome of Hagia Sophia in Constantinople. Diatomaceous earth is used in the manufacture of dynamite under the name of kieselguhr. Dynamite is essentially nothing but nitroglycerine absorbed into the interstices of dried diatomaceous earth.

Perhaps the most important application of diatomaceous earth is in the production of insulating and heat-resistant materials. This makes available extremely light fire-bricks suitable for the vaulting of furnaces, marine boilers, etc., and for sound-proof partitions and ceilings.

A strange use for diatomaceous earths was found by the poorest inhabitants of Lapland, Bohemia, Hungary and Italy, and also of Java, Mexico, and Tierra del Fuego, who add the earth to food under the name of erdmehl, bergmehl, or mountain meal, apparently in order to attain a feeling of repletion after a too scanty allowance of nourishing food!

How many kinds of diatoms are there? Science recognises some 200 genera, comprising 8000 to 10,000 species, but new species are ever being added to the list. When one realises that the literature on diatoms is very scattered and that in order to identify a specimen scores or even hundreds of pictures may have to be scrutinised, one begins to understand why there are only about 200 serious diatomists in the whole world.

ROBERT BOYLE: engraving by R. Woodman.

FIG. 1.—Boyle's air pump.

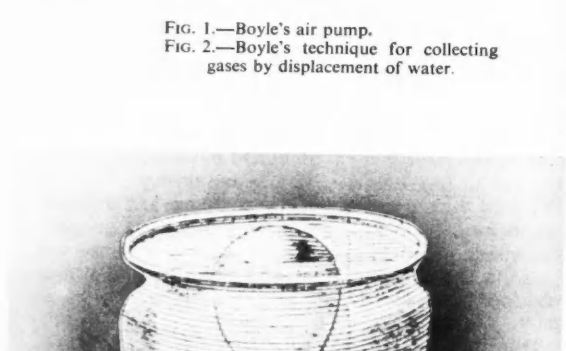


FIG. 2.—Boyle's technique for collecting gases by displacement of water.

The Hon. Robert Boyle (1627-91) Chemist

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ROBERT BOYLE lived in an age when it was still possible for one man to be well acquainted with the whole range of the sciences and to make outstanding original contributions to several of them. Among his contemporaries we may name Hooke, in particular, and also Sir Christopher Wren for such versatility, a versatility that Boyle himself shared. His contributions to physics have recently been discussed in this journal (*see* C. L. Boltz, DISCOVERY, 1950, Vol. II, 399–402).

His great services to the progress of chemistry have too often been treated as if his place in the history of the science to which by choice and inclination alike he devoted most of his time and interest in natural philosophy, especially the 'new philosophy' by means of experimentation, depended on what he wrote in his *Sceptical Chymist* (London, 1661); and much of his extensive and varied experimental record still remains largely unknown except to those who have the time and opportunity to read the great number of treatises and memoirs that flowed from his prolific pen, and from his laboratory as well as from his study, in an unbroken sequence for over thirty years. And something of interest or importance for his favourite science, chemistry, often appears in the least expected places.

After Boyle's return from the Continent in 1645—he was then a young man of eighteen—he settled next year in his manor of Stalbridge, Dorset, in 1646, determined after some acquaintance with the *virtuosi* of the new scientific movement, some of whom he had met in London at the house of his sister, Lady Ranelagh, to be a follower of Lord Bacon, whom throughout his life he was to regard with the highest veneration, and, for no reason that we can now specify, to devote himself to chemistry.

At Stalbridge he spent six years and established a laboratory; he made frequent visits to London to meet and hold discussions with the *virtuosi*. But Stalbridge had its drawbacks and apparatus was broken in transit over the roads from London; new furnaces that he had ordered arrived in fragments. Writing to Lady Ranelagh about one of these disasters, not without moralising on it and on the disturbed state of his country in his characteristic manner and with his sharp disappointment showing through his words, Boyle said:

> "That great earthen furnace, whose conveying hither has taken up so much of my care, and concerning which I made bold very lately to trouble you, since I last did so, has been brought to my hands crumbled into as many pieces, as we into sects; and all the fine experiments, and castles in the air, I had built upon its safe arrival, have felt the fate of their foundation. Well, I see I am not designed to the finding out the philosophers stone, I have been so unlucky in my first attempts in chemistry. My limbecks, recipients, and other glasses have escaped indeed the misfortune of their incendiary, but are now, through the miscarriage of that grand implement of *Vulcan*, as useless to me, as good parts to salvation without the fire of zeal. Seriously, Madam, after all the pains I have taken, and the precautions I have used, to prevent this furnace the disaster of its predecessors, to have it transported a thousand miles by land, that I may after all this receive it broken, is a defeat, that nothing could recompense, but that rare lesson it teaches me, how brittle that happiness is, that we build upon earth."

Then came another interruption, lasting two years (1652–4), that had to be spent in Ireland attending to his property. But in 1654 he moved to Oxford, where he remained until he moved to London in 1668, and where, under the influence of Wilkins and others, he may be said to have begun his scientific work; and from there he published his first scientific book, *New Experiments Physico-Mechanicall, touching the Spring of the Air and its Effects, (made, for the most part, in a New Pneumatical Engine)*, etc. (Oxford, 1660).

It is not too much to say that the *New Experiments* was Boyle's greatest experimental work. It rapidly brought him a high reputation throughout the scientific world of Europe. Although not indicated in its title, the book contained a large number of important chemical experiments, in fact, the first series of experimental studies in the modern age of science on the problems of combustion and respiration. By means of the air-pump (Fig. 1), constructed for him by Hooke, Boyle showed that ignited combustibles, such as candles, tapers, charcoal, and "a piece of Match, such as Souldiers use" were extinguished when the air was evacuated by means of the pump from the receiver in which they had been placed; and similarly that a lark, a sparrow and a mouse, successively enclosed in the receiver, did not survive the 'exsuction' of the air. He found also that rapid removal of the charcoal from the receiver into the open air revived the combustion. If the air was not removed, both fire and life persisted in the receiver for a limited time; in the open air they continued without interruption. In the unevacuated receiver, a mouse lived for a whole night in the air that it contained. Although Boyle could arrive at no detailed explanation at this time, he had demonstrated experimentally the necessity of air for fire and life; hitherto this had been known from everyday experience, rather than scientific experiment.

He rebutted a commonly held explanation about the extinction of fire in enclosed spaces by means of a simple experiment, which he recorded here. It had been thought that fire in enclosed spaces was extinguished by the fumes that it produced; but, when Boyle included together with an ignited combustible in the receiver a bladder partly filled with air and tied at the neck, the fire went out on evacuation of the air and the bladder expanded, showing, as he pointed out, that the air in the bladder was expanded and, therefore, that the fumes, which seemed to fill the receiver, could not have prevented the air that remained in the receiver from expanding likewise. He noted that Paracelsus had said that the lungs consumed part of the air and rejected the rest, as the stomach concocted meat, using one part of it and rejecting the other, whence it seemed that

air contained "a little vital Quintessence", but this, said Boyle, required proof, not mere assertion.

In the *New Experiments* of 1660 Boyle describes what we would now call the collection of gases by the displacement of water. He regarded the operation as the collection of 'air' generated anew from a reacting mixture: and he collected it, from the interaction of an acid and a metal, in a glass vessel inverted over water, previously filling the vessel with "Oyl of Vitriol and fair water, of each almost a like quantity, and casting in half a dozen small Iron Nails", repeating the experiment with *aqua fortis* (concentrated nitric acid) in place of oil of vitriol.

So far as we are aware, it was Boyle who initiated this method, one of the most important practical advances in the history of chemical discovery. It is not without interest to know when he invented this technique; the *New Experiments* was published in 1660, and Boyle had evidently devised and used the method before this date, since the book, "written by way of Letter to the Right Honorable Charles Lord Vicount of Dungarvan", as the title-page states, is subscribed on its last page "*Becon's-field* this 20th of December, 1659". The method is usually ascribed to Mayow, who gave the first illustration of it in his *Tractatus quinque medico-physici* (Oxford, 1674), from which a reproduction is shown here (Fig. 2). It was, however, Boyle's device, not Mayow's.

Next year, in his *Certain Physiological Essays* (London, 1661), Boyle showed how chemical and physical properties might be satisfactorily explained in terms of atoms or corpuscles of different shapes and motions or, as he wrote, "by little bodies variously figur'd and mov'd"; and he emphasised that this way of looking at these problems was more intelligible and more in agreement with many facts than the scholastic attempt to explain the properties of substances "from certain substantial Forms, which the most ingenious among themselves confess to be Incomprehensible, and certain real Qualities, which knowing men of other Persuasions think to be likewise Unintelligible".

In these *Essays* Boyle adopted atomistic ideas; and by his later and widespread application of these ideas he came to be looked upon as the restorer of 'mechanical philosophy' in England. Although the ancient Greek atomic theory has a continuous history through the centuries, it had been brought into much greater prominence in Boyle's day through the writings of Gassend (1592–1655) and the 'corpuscular philosophy' of Descartes; and, in England, Walter Charleton had recently (1654) produced his *Physiologia* (London, 1654), the first English book on atomism. But it was Boyle who propagated and applied these ideas; and it seems that it was Boyle who influenced Newton in the adoption of atomism—Newton being, in fact, a more thorough-going atomist than Boyle.

The year of 1661 saw also the publication of the first edition of Boyle's *Sceptical Chymist* (London, 1661), which contained an elaborate and destructive criticism of current chemical theories about the elements said to compose the multitudinous variety of substances in Nature. These two theories were, first, the ancient Greek theory of the four elements (earth, water, air and fire), propounded by Empedokles in the fifth and adopted by Aristotle in the fourth century B.C., and, second, the theory of the three principles—salt, sulphur and mercury—recently propounded by Paracelsus in the early part of the sixteenth century.

Boyle disposed of the belief that fire resolved bodies into their component elements by many facts drawn from well-known chemical observations. For example, the nature and number of the products depended on how the fire was applied, either 'in an open fire' or 'distilled in a retort', *i.e.*, either by burning or distillation; he noted that wood treated by the former method was "sequestred into ashes and soot", into two products, but subjected to the latter yielded oil, spirit, vinegar, water and charcoal, five products. So that "the operation of fire may be diversified by circumstances" and therefore fire was not "the genuine instrument of analysing mixt [i.e. compound] bodies". Again, in an instance where one knew the components, soap cannot be resolved by fire into the substances of which it has been made. Boyle pleaded for closer thinking and stricter regard for chemical facts; and, to clear a way through the fog of subtleties inherited from scholastic thought, he defined the chemical element: "I mean by Elements, as those Chymists that speak plainest do by their Principles, certain Primitive and Simple, or perfectly unmingled bodies; which not being made of any other bodies, or of one another, are the Ingredients of which all those call'd perfectly mixt [i.e., compound] Bodies are immediately compounded and into which they are ultimately resolved."

He pleaded also for a clearer style in writing and the avoidance of dialectical subtleties which "are wont much more to declare the wit of him that uses them, than increase the knowledge or remove the doubts of sober lovers of truth. And such captious subtleties do indeed often puzzle and sometimes silence men, but rarely satisfy them". Chemistry must abandon the magic of words and phrases; and chemists must begin at the right end, with experiments, with facts. However, he has a good word to say about the chemists despite the obscurities of their books: "Methinks the chymists, in their searches after truth, are not unlike the navigators of Solomon's Tarshish fleet, who brought home from their long and tedious voyages, not only gold, and silver, and ivory, but apes and peacocks too; for so the writings of several (for I say not, all) of your hermetick philosophers present us, together with divers substantial and noble experiments, theories, which either like peacocks' feathers make a great shew, but are neither solid nor useful; or else like apes, if they have some appearance of being rational, are blemished with some absurdity or other, that when they are attentively considered, make them appear ridiculous." Boyle was, unfortunately, unable to apply his definition to draw up a list of chemical elements or even to indicate any one element; but, substantially, it was Boyle's definition that was applied by Lavoisier in 1789 when he drew up the first table of chemical elements as "substances that had not been decomposed". The opinion of Boyle's immediate successors was voiced by John Freind, Professor of Chemistry in Oxford, in his *Chymical Lectures* (London, 1712): "We own Chymistry has made a very laudable Progress in Experiments; but we may justly complain, that little Advances have been made towards the Explication of 'em. . . . No Body has brought more Light into this Art than Mr. *Boyl*, that famous Restorer of Experimental Philosophy: Who nevertheless has not so much laid a new Foundation of Chymistry, as he has thrown down the old."

In his *Experiments and Considerations touching Colours*

(London, 1664), Boyle announced an important chemical observation that syrup of violets gave a red colour in acid and a green one in alkali and pointed out that this could be used as a test. He investigated the properties of other similar juices of flowers and showed that they had similar properties. This marks the introduction into chemistry of indicators for acids and alkalis.

Two years later he published his *Origine of Formes and Qualities* (Oxford, 1666), in which he presented a detailed criticism of the scholastic doctrine of 'Substantial Forms' as accepted by some of his contemporaries and pleaded rather for the explanation of the properties of bodies, not from alleged innate qualities, but rather from the effects on the senses of the texture and motions of their component particles, in other words, for mechanical explanations of phenomena. Indeed, he noted, almost all rational accounts of difficult phenomena had been given by such as either did not acknowledge or took no notice of Substantial Forms; and no such Form was necessary in the clear solutions of statics, hydrostatics and pneumatics. Aristotle himself did not explain even one phenomenon intelligibly by means of a Substantial Form. And how, asked Boyle, could one explain a phenomenon by recourse to an uncomprehended Form? It might, of course, be more easy than satisfactory; and we are told the agent, "not how the effect is wrought", which leaves us "as much to seek for the *causes* and *manner* of particular Things, as Men commonly are for the particular causes of the several strange Things perform'd by Witchcraft, though they be told, that 'tis some Divel that does them all". The causes of chemical and physical changes in bodies are to be sought, not in Substantial Forms, but in "the catholick and fertile principles, motion, bulk, shape, and texture of the minute parts of matter". In the *Cosmicall Qualities of Things* (Oxford, 1671), Boyle repeated these ideas.

In 1672 in his *Tracts . . . containing New Experiments, touching the Relation betwixt Flame and Air* (Oxford, 1672), Boyle returned to the study of combustion, but made little progress. He observed the inflammability of the 'fumes' (hydrogen) from 'saline spirit' and steel filings; and he reported the successful burning under water of previously ignited gunpowder packed in a goose-quill. (Hooke knew this in 1665 and considered that air and nitre contained a common constituent, necessary for fire and life.)

Next year there appeared one of the most interesting of Boyle's chemical studies, *Essays of Effluviums* (London, 1673), in the tracts appended to which he described over thirty experiments on the gain in weight of metals on calcination, the first extensive research on this problem. Some of the experiments were made in sealed vessels; the vessels contained weighed amounts of the metals; the metals were removed after the calcination and the breaking of the seal and were found to have gained in weight. The increase Boyle ascribed to the addition of material particles of fire which had passed through the pores of the glass material of the vessels. This explanation was widely adopted by his successors, even during the period of the phlogiston theory; and it was not discordant with scientific thought when heat was looked upon as material.

In 1674 Boyle gave his considered opinion on the problems of combustion and respiration in his *Tracts containing Suspicions about some Hidden Qualities of the Air* (London, 1674). Four years earlier, he had reported to the Royal Society an experiment in which he had placed a mouse in a glass vessel together with a mercury gauge, sealed the vessel and found that there was no change in the 'spring' of the air after the mouse had respired in the included air for two and a half hours (*Phil. Trans.*, 1670, **5**, 2046–7). In the *Tracts* of 1674, Boyle stated that he had proved the same to be true of air in which a flame had expired and he therefore concluded that "The Difficulty we find of keeping Flame and Fire alive, though but for a little time, without Air, makes me some times prone to suspect, that there may be dispers'd through the rest of the Atmosphere some odd substance, either of a Solar, or Astral, or some other exotic, nature, on whose account the Air is so necessary to the subsistence of Flame. . . . And indeed it seems to deserve our wonder, what that should be in the Air, which inabling it to keep flame alive, does yet, by being consum'd or deprav'd, so suddenly render the Air unfit to make flame subsist. And it seems by the sudden wasting or spoiling of this fine Subject, whatever it be, that the bulk of it is but very small in proportion to the Air it impregnates with its virtue. . . . And this *undestroy'd springyness* of the Air seems to make the necessity of fresh Air to the Life of *hot* Animals . . . suggest a great suspicion of some *vital substance*, if I may so call it, diffus'd through the Air, whether it be a *volatile Nitre*, or (rather) some *yet anonymous* substance, Sydereal or Subterraneal . . ." (In this same year, 1674, Mayow published his *Tractatus quinque* and, by experimenting over water instead of in closed receivers, was able to demonstrate the consumption of part of the air in combustion and respiration.) This was the nearest advance that Boyle made to the discovery of oxygen.

The last important chemical work published by Boyle was his *Aerial Noctiluca* (London, 1681) and his *New Experiments and Observations, made upon the Icy Noctiluca* (London, 1681–2). These two tracts dealt with the preparation of phosphorus and with its glow. After receiving some information from various sources in 1677–80, Boyle succeeded in preparing phosphorus in suspension or solution in 1680 and solid phosphorus in 1681; and, although this substance had been obtained earlier both by Brand and Krafft, Boyle, in 1680, gave the first published account of the method of preparation (see Partington, *Science Progress*, 1936, Vol. 30, 402). Until quite recent times, Boyle's observations on the glowing of phosphorus, including its dependence on air, the production of an acid different from that obtained in the burning of phosphorus the glowing of phosphorus in solutions in various oils and its inhibition in others, the detection of minute proportions of phosphorus in solution by the glow and the strong odour produced in the surrounding air when the glow occurred, have not been surpassed, as has been pointed out by Partington (*loc. cit.* and *Text Book of Inorganic Chemistry*, 5th edition, London, 1946, p. 609). It is interesting to note that twelve years earlier Boyle had demonstrated that the luminescence of 'shining wood', i.e. of living fungi, depended on the presence of air: having placed some 'shining wood' in a receiver, he pumped out the air and found that "we could not perceive any light at all to proceed from the wood" (*Phil. Trans.*, 1667–8, vol. 2, p. 581), probably the first observation ever made on this phenomenon and one that he recalled when he came to experiment with phosphorus.

The Earthworm and the Soil

R. H. FERRY, F.Z.S.

THE earthworm's manifold activities in increasing soil fertility have long been appreciated by man. As early as 1770 the naturalist, Gilbert White, wrote that *the soil soon becomes cold, hard bound, and void of fermentation and consequently sterile* without the agency of earthworms. Later Darwin opened the gate wide into the vast field of earthworm research, particularly in relation to soil fertility. But so often the cart in this field of research has been put before the horse; many early investigations, carried out without any accurate knowledge of the life history and habits of earthworms, were doomed to failure at the outset. It is in fact only in comparatively recent years that research workers have started to delve deeply into matters of earthworm ecology; a serious and thorough study is now being made at Rothamsted Experimental Station and elsewhere of this subject. When this work has been concluded we shall no doubt be in a better position to estimate the role that these animals play.

A first essential is to be able to identify and classify all the various species of earthworms, and to trace their distribution.

All the earthworms found in this country belong to the family Lumbricidae. This is the dominant European family and comprises 220 species. About 19 species are fairly common throughout most of Europe and they have spread to many parts of the world. Experts on their distribution distinguish two main groups of earthworms—the *native* and the *peregrine*. The native species are those which were present before the Ice Age and which survived through that period. It should be made clear that the rather ambiguous term *peregrine* is applied to the species which have evolved since the Ice Age, and which have moved from country to country, either through the agency of man or by their own volition. Dr. L. A. C. Evans and the late L. Cernosvitov in their *Synopsis of British Fauna—Lumbricidae* state that the region in which the native species occur comprises the Eastern parts of the United States, Southern Europe, Northern Africa, Egypt, Palestine, Syria, Caucasus, Persia, Northern India as far as the south of Calcutta, Manchuria, Korea and Japan. While the southern boundary of this region is obviously created by arid land and by seas, the northern boundary cannot now be explained by geographical conditions which are not suitable to earthworms. It is probable, however, that the native worms north of this line were exterminated by the Ice Age, for the northern extent of the ice cap corresponds with the geographical limit in which earthworms are found. This northern border runs through Southern Ireland and England, North France and along the northern frontier of Czechoslovakia, Southern Russia including Turkestan, part of North China, Manchuria, Japan and Korea. The farther north we go, therefore, we expect to find fewer native species compared to the peregrine. In Germany, for instance, the earthworm fauna comprises 24 species, of which as many as 19 are peregrine, whereas in Italy 17 only out of a total of 57 species are peregrine. In the British Isles there are 35 species; 17 are peregrine. Ten peregrine species are well-known in the top foot of cultivated land; three are common in dung hills, four are sometimes found in cultivated land, and the remainder have much more specialised habitats, living under stones and in the muddy banks of streams, etc.

It is impossible here to go into the internal and external anatomical differences between species which must be used for the purposes of identification; but an extremely useful key ot the common British species is given in the *Synopsis of the British Fauna*, published by the Linnean Society of London, which cannot be too highly recommended to students.

As each worm contains both male and female sex organs they are hermaphrodites. When copulating there is an exchange of sperm, which is stored in special receptacles and remains active for a considerable time. It is, however, possible in some species for fertilisation to take place in a worm without the agency of sperm from another. In these cases the ova and spermatozoa of a single individual either pass independently into the cocoon, or spermatozoa enter the ovisac so that fertilisation takes place internally before oviposition. While some species can be seen in the act of copulation on the surface of lawns and fields in the dew of the evening or early morning, others—such as *Allolobophora caliginosa* mate underground. The eggs are laid in oval-shaped cocoons, produced by the girdle or clitellum, the swelling seen in adult worms. The clitellum contains glandular cells some of which form the tough envelope of the cocoon, and others contain a viscous fluid which fills the cocoon and supplies nourishment to the growing worm. The eggs are expelled from the body through the female pores present in one of the segments, but the actual clitellum is situated farther back. The position of the clitellum and the number of segments it covers is constant in each species, and is an important external character that can be used for identification purposes. The number of eggs deposited in each cocoon varies according to the species; in the common brandling worm found in manure heaps (*Eisenia foetida*) there may be as many as 20 eggs per cocoon, while the green worm often found on the grass verges of roads (*A. chlorotica*) lays cocoons containing one egg. The number of young worms that actually come out of the cocoon also varies widely. Only two, out of fourteen species studied, frequently produce more than one worm per cocoon, the other embryos failing to mature.

Not all worms produce cocoons all the year round. In many species there is a rest period when they burrow deeper into the subsoil as a definite reaction to the top soil being too dry. In *A. longa* and in *A. nocturna*, however, there is a fixed resting period during the summer, which is not broken until the autumn.

The incubation period of the cocoon varies: in *Eisenia foetida* it is 11 weeks; in *O. lacteum* it is 21 weeks. The period from hatching to sexual maturity also varies widely with the species and depends to a great extent on the time of year a which the cocoons are deposited and the young worms emerge. In *A. longa*, cocoons emerging in April reach sexual maturity in 71 weeks, while those emerging in the following February take only 40 weeks. In my experience the approximate time that *Lumbricus terrestris* takes to reach maturity is 6 months.

It is obviously impossible to estimate the longevity of any given species under field conditions when all members are exposed to attacks from birds, moles and insects, but under artificial conditions it is known that the life is comparatively long. The German zoologist, Korschelt, has concluded under artificial conditions that *E. foetida* live up to 4½ years, *L. terrestris* up to 6, and *A. longa* from 5½ to 10¼ years.

For years man has been trying to calculate the population of earthworms in various types and conditions of soil, but even in recent counts the figures arrived at can only be approximate. The new method, however of bringing worms to the surface for the purpose of making a census of numbers is far more efficient than the old one of simply digging for them, for the vibration of digging frightens many worms lower into the subsoil. In the new technique an area of earth is saturated with a solution of permanganate of potash, which forces the worms to the surface. Even so a certain percentage of worms do not completely surface, and if the soil is wet or of a clayey character, they cannot be retrieved by digging.

Darwin marvelled at the number of worms per acre, but his estimate of 53,000 on arable land was considerably lower than recent estimates. In 1922 Morris found one million earthworms per acre on a plot fertilised with farmyard manure at Rothamsted, but the number dropped sharply to half a million on a plot that had received no manure since 1843. This is a very obvious pointer to the earthworm's preference for well-fed and fertile soil. Using the 'permanganate of potash' technique in Rothamsted investigations, an estimate was made of 2–12 cwt. of earthworms per acre of grassland according to the age of the pasture—the oldest grasslands showing the greatest weight of worms. In DISCOVERY (March 1948) A. C. Evans states that 200,000–653,000 worms per acre were found in grass fields over five years old, and that in arable fields the number fell to approximately 100,000 per acre.

Earthworms seize leaves and other objects not only for food but for plugging up the mouths of their holes: this is in fact one of their strongest instincts, as can be seen on any lawn in the autumn and early winter. Leaves, bits of decaying vegetable matter, hair and feathers, all serve the worm to good purpose as a front door to its burrow. These objects used to block the hole are not always gnawed, though there is no doubt that leaves are stored in this way for future consumption, and often a quantity of leaves, sealed together with moist viscid earth ejected through the body, is stacked up over the hole far in excess of the 'hole-stopping' requirements. When leaves are not available, stones are frequently heaped up as a barricade, this being done by suction—a big worm is capable of dragging a stone weighing 2 ounces. As a rule such operations are carried on at night. It is unusual for a worm to lose a grip on its burrow with its tail, so that it may go into reverse quickly and regain shelter, yet on occasion worms will sally forth and explore the ground for many yards around, finding their way home by instinct.

Though at first it may seem obvious, there is some doubt as to why worms plug their holes. Plugging would seem to advertise the worm's position underground rather than protect it from its enemies, birds and centipedes. Neither would leaves or stones prevent the hole from being flooded in heavy rain. The problem remains, though it is now generally agreed that worms plug their holes to protect themselves from the cold stratum of air that hangs low over the ground. Protection from enemies may be a subsidiary cause.

Earthworms also swallow stones up to 1/12th of an inch in diameter, thus a continual passing up of soil to the surface in the form of the well-known worm casts, eventually results in a layer of stone-free surface soil of 4–8 inches in depth. Working along these lines Darwin was the first to make an estimate of the amount of soil that earthworms throw up to the surface in a year; he calculated that it was from 8–18 tons per acre—the equivalent of 320,000,000 tons spread over the whole of England. It has been recently calculated that the time required for the top four inches of soil to pass through the alimentary tract of the earthworm population is from 11½ years in old permanent pastures with a high population, to 80 years on arable land with a lower population.

The casts are not, however, in themselves an indication of the abundance of worms beneath the surface, or of the worm activities in progress. Neither does the weight of the worm casts represent the total weight of the soil swallowed by the worm and ejected to the surface, for a certain amount is retained for the lining of the burrows. A far bigger factor, but one which nevertheless must be taken into consideration, is the activity and consumption of earth by the species present which do not produce worm-casts. For the purpose of estimating the amount of earth voided underground by the non-casting species, it has been assumed in recent investigations that it is equal in amount, weight for weight, to the amount ejected to the surface of the ground by the familiar worm-casting species. Having ascertained the weights of soil moved by the two groups, the casting and the non-casting species, it is quite possible to estimate the total amount of soil swallowed by worms in a given area.

Though the worm-casting species are considered the most valuable from the agriculturist's point of view, farmers, market gardeners and horticulturists should not entirely gauge the fertility of their soil by the number of worm casts appearing on the surface. An investigation in the Claycroft field at Rothamsted showed only two tons per acre of worm casts, whereas the total soil consumed per acre was as high as 19 1 tons, directly due to the presence of a large number of non-casting worms, the soil voided below through the digestive system of the worms being calculated at 17 1 tons. On the basis of our present knowledge all the species of the genus *Allolobophora* form casts on the surface while as far as we know at present, the others do not.

The gardener and the greenkeeper have of necessity a different outlook on worm casts; they consider them an unmitigated nuisance; they recognise that the worms do inestimable good in revitalising the soil, but the casts make the surface of the turf uneven and unsightly. This matter is not being overlooked in the course of present investigations. It may soon be possible to scatter insecticide powder to deal with the worms that surface to feed at night. As the chemicals will not be strong enough when they have been washed into the soil and diluted by rain to be harmful to the non-casting, non-surfacing worms, their beneficial activities below the soil will be retained. When these investigations have been brought to a conclusion, it will be possible to have velvety bowling greens and putting greens, due mainly to the earthworm's activities, without the hindrance of worm casts.

Far and Near

Funds offered for International Harwell

OFFERS have come from Italy and France of financial help which will enable Unesco to start studying the possibility of setting up a West European Physics Laboratory for High-energy Particles. An offer of 2,000,000 lire from the National Research Council of Italy was accepted by Unesco, and the French Government is considering making a donation of 2,000,000 francs. The study is to be made under the direction of Unesco's Natural Science Department.

The proposal for such a laboratory was made by Professor Isidor I. Rabi, Nobel prize-winner in physics, on behalf of the U.S. delegation. (See DISCOVERY, Aug. 1950, p. 269.) It is the view of Professor Pierre Auger of Unesco that the West European physics laboratory should house a cosmotron—a giant machine which would bring into the laboratory particles carrying enormous energy. These particles are at present under study through investigation into the cosmic rays from outer space.

A preliminary report on the project will be presented to a meeting of experts to be convened by Unesco.

Week-end Courses in Freshwater Biology

THE world-famous Educational Museum at Haslemere has acquired three acres of woodland adjoining its grounds and also a building for use as a laboratory and lecture room. The land is to be used for the study of freshwater biology; it consists of a valley watered by small streams and springs and containing a dozen ponds. Week-end courses are to be organised, particularly for teachers and adult students, and the first will be held at Whitsun in co-operation with the Extra-mural Department of London University.

Physical Societies' Exhibitions

THE Physical Society's annual exhibition is being held at the Imperial College of Science and Technology, S. Kensington, from April 6 to 11. The 48th Exhibition of Scientific Instruments and Apparatus organised by the French Physical Society will be held in the salons of the Sorbonne, from May 11 to 17 inclusive. Simultaneously an independent exhibition of British Scientific Research Instruments will be held at the Sorbonne. University and Government laboratories will participate in this exhibition, as well as private British industrial firms.

Science Masters' Association

WE are informed by the Science Masters' Association that the membership is over 4000, representing 1792 schools.

Hydroponics

A BOOKLET on the "Soil-less cultivation of Perpetual Carnations" has been published by the British National Carnation Society (23 Russell Chambers, Covent Garden, London, W.C.2). It costs 5s. *post free*, and provides details about how to run hydroponic tanks using the sub-irrigation system; recipes for suitable culture solutions are given, there is a section on the use of Vermiculite (which has advantages over sand or soil composts) and there are some really impressive photographs of carnation plants grown without soil.

Air Photography and Archaeology

A LECTURE to the Royal Society of Arts (Feb. 21) by Dr. J. K. S. St. Joseph of Cambridge University showed why air photography is now an established means of assisting the archaeologist in his discoveries.

By recording the earth's surface comprehensively the aerial camera reveals not only the major and obvious features, but also minute detail, which otherwise escapes observation.

Any landscape is the result of development by nature and by man, and superimposed features over the centuries leave their mark on the surface in some way or other. Protrusions, such as archaeological remains, can easily be studied on the ground, but hidden structures, like foundations, which have been camouflaged by agricultural progress and are often invisible to the pedestrian, can be effectively photographed from the air in the morning or evening sunlight when minor features are thrown up in faint relief.

Air photographs can reveal buried sites of which there is no surface trace whatever. The fact that the land has been ploughed up over a long period does not prevent discovery, as the air observer can detect the formation by differences in the soil or in the colour and growth of the vegetation. Not only the existence of sites, but even their character and period can also be clearly perceived in this way. Long-rooted cereals generally give the most sensitive renderings of such hidden features; root crops often just a blurred image, while grass, except in drought conditions, is seldom responsive. Thus, if a site is observed over a period of years and the land is under crop rotation, sooner or later the required information will be obtained by means of the camera in the air. The problem today is not lack of sites for observation, but how best to record the details in the limited periods available, as each group of subjects has its particular season when it can best be photographed.

Some outstanding examples of the application of air photography to archaeological knowledge are the Stonehenge Avenue, the prehistoric religious site at Dorchester, Celtic fields on Salisbury Plain, and Roman town-plans at St. Albans and many other places. Discoveries of new religious monuments have been made at Birrens (Dumfriesshire), Coupland (Northumberland) and Elston (Notts.), and a large number of Iron Age hill forts have been discovered and photographed. In addition, our knowledge of the military and civil districts of Roman Britain has been enlarged. The aerial camera has revealed military sites on Watling Street, and public buildings, shops, houses and even mosaic or concrete floors in the old tribal capital of Wroxeter in Shropshire.

The early history and prehistory of Britain can thus be studied in a fascinating and effective way from the air. Owing to great building projects, open-cast mining, afforestation and agricultural development the surface of Britain is undergoing a much swifter change than ever before. Visible archaeological remains can be preserved, but hidden sites, which often contain greater historical material are not taken into account. Air photography is the answer in compiling a planned national survey for record purposes. Time is short, and the opportunity to do it may, in many cases, not occur again.

Polystyrene

THE short article on polystyrene (Feb. issue 1951, p. 56) stated that with the announcement by Monsanto, that their Newport plant is about to produce polystyrene. Actually Monsanto Lustrex polystyrene has been in bulk production since July, 1950.

The article also stated that "British Petroleum Chemicals, a joint venture of the Anglo-Iranian Oil Co. and Distillers Ltd., will also be making the monomer, styrene. It is this monomer incidentally, which Monsanto will use when the styrene is in production at Grangemouth." This is incorrect. The styrene will be manufactured by Forth Chemicals Ltd., a new company formed by Monsanto Chemicals Ltd., and British Petroleum Chemicals Ltd. (the latter being owned jointly by Anglo-Iranian Oil Co. Ltd. and Distillers Co. Ltd.).

W. African Fisheries Research

BUILT with funds supplied by the British Government, a research ship was launched recently (Feb. 22) at the shipbuilding yard of Hall Russell & Co. Ltd., Aberdeen, which will aid materially the campaign to improve fishing methods in West Africa.

The ship will be used by the scientific staff based at the Laboratory of the West African Fisheries Research Institute at Kissy, near Freetown, Sierra Leone. Its first expedition will be devoted to an investigation of the quantity and species of fish in grounds off the W. African territories to study seasonal migration. Experiments will be made to find the best methods for surface, mid-water and bottom-sea fishing.

The ship has accommodation for two scientific officers. Its radius of operations will extend from Bathurst to the Cameroons, and possibly as far south as Ascension Island.

The vessel, which has a 350 h.p. diesel engine, will be supported by two motor-boats, one of which will be equipped with an echo-sounder for locating shoals of fish and studying their movements. The ship's general equipment includes direction-finding apparatus, a refrigerated fish room, echo-sounders and a liver-oil extractor. A small laboratory is also fitted in the deck-house aft.

Night Sky in April

The Moon.—New moon occurs on April 6d 10h 52m, U.T., and full moon on April 21d 21h 30m. The following conjunctions with the moon take place:

April					
5d 00h	Jupiter in conjunction with the moon		Jupiter	2°	S.
7d 12h	Mars	,,	Mars	4°	S.
8d 02h	Mercury	,,	Mercury	1°	S.
9d 13h	Venus	,,	Venus	4°	S.
9d 14h	Saturn	,,	Saturn	4°	N.

In addition to these conjunctions with the moon, Mercury is in conjunction with Mars on April 19d 08h., Mercury being 2·8° N.

The Planets.—Mercury is an evening star during part of the month, its times of setting on April 1 and 15 being 20h 15m, and 20h 20m, respectively, but later it becomes a morning star and at the end of the month rises about 20 minutes before the sun. Venus is an evening star, setting 3h, 3h 20m and 3h 40m after the sun on April 1, 15 and 30, respectively, stellar magnitude −3·5 and the visible portion of the illuminated disk varying between 0·84 and 0·74. On April 1 Mars sets an hour after the sun but draws too close to the sun throughout the month for favourable observation. Jupiter is too close to the sun early in the month to be observed but is a little better placed for observation towards the end of the month, rising an hour before the sun on April 30, when it can be seen for a short period in the eastern sky. Saturn sets in the morning hours—at 5h 35m, 4h 37m, and 3h 37m, on April 1, 15, and 30 respectively. The planet is a little N. of β Virginis and throughout the month has a small apparent motion in a westerly direction.

The bright star Capella in the constellation of Auriga, and one of the most brilliant stars in the heavens, is conspicuous at this time of the year. A line drawn through γ and β Urs. Maj, that is through the third and second stars of the Plough, and prolonged about five times the distance between these stars, will pass near Capella. Its distance from us is not very great, only about 50 light-years (a light-year is practically 6 million million miles), and it is 170 times as luminous as the sun, so if placed as near to us as the sun is, we should be dazzled by its brightness. It is a very close double star but this was not known by means of the telescope—it was detected by the spectroscope which has shown a large number of stars to be doubles—or more correctly binaries—because they are physically connected, each revolving round the centre of gravity of the system.

More Feeding Stuffs from Fisheries Waste

WASTE from British fisheries that is usually thrown overboard can be made into a good palatable feeding stuff for animals. Recent work at the Torry Research Station has proved that the material is capable of giving a yield and type of meal as good as that obtained from the usual fish offal.

The amount of guts available for processing into meal is about 6% of the landed weight of the fish, but it is doubtful if all of this could be brought back to port. What could be brought back, however, would still be a useful addition to the supply of raw material for the fish-meal manufacturer. The main difficulty about bringing guts back to port is that they putrefy rapidly. Tests made by the Torry Research Station were designed to find a satisfactory method of preserving the guts a week or two. The most satisfactory method was found to be mixing 0·4% by weight of formaldehyde. No putrefaction was detectable after nine days.

A large sample of meal was prepared by a commercial fish meal firm from guts preserved in this way and this and other samples made by the Torry Research Station were tested for possible toxicity by feeding them to rats. There was no evidence of any toxicity in any sample. The meal has been later safely fed to pigs.

Research on Cosmic Rays

IN a Royal Institution lecture on Feb. 16, PROF. C. F. POWELL, of Bristol University, said the two principal problems met with in cosmic-ray research are: (1) to detect the radiation, measure the masses, energy and transformation properties of the particles composing cosmic radiation, and to study the nuclear transmutations they produce; (2) to develop ways of making such observations throughout the atmosphere and in the depths of the earth.

Referring to experiments made at great altitudes, he said some information has been obtained by means of V2 rockets; these pass almost completely out of the earth's atmosphere, but their time of flight is restricted to only a few minutes.

Balloons can be made to ascend to altitudes of the order of 100,000 ft., and to give level flights for many hours. The simplicity of the photographic method of recording the tracks of charged particles (it was work on this technique that won Professor Powell his Nobel Prize) makes it very suitable as a detector in such experiments.

By observations at great altitudes we now know that the primary cosmic radiation is made up of atomic nuclei moving at speeds closely approaching that of light. It is possible to determine the mass of the incoming particles and the relative abundance of the different chemical elements. Recent experiments prove that hydrogen and helium are the most frequent, and the distribution in mass of the heavier nuclei appears to be similar to that of the matter of the universe; thus elements more massive than iron or nickel occur, if at all, very infrequently.

The detailed study of the 'mass-spectrum' of the incoming nuclei has an important bearing on the problem of the origin of the primary particles, but it is complicated by the fact that, because of their large charge, they rapidly lose energy by making atomic and nuclear collisions in the atmosphere. They therefore rarely penetrate to altitudes less than 70,000 ft. It is for this reason that exposures at high altitudes are of particular interest.

A second reason for making experiments at extreme altitudes is that the primary nuclei commonly suffer fragmentation in making nuclear collisions. A primary nucleus of iron, for example, may decompose into lighter nuclei such as, say, sulphur, lithium, α-particles and protons. The mass spectrum at a given depth is therefore different from that of the primary radiation, and such effects are appreciable at 90,000 ft. where the mass of overlying air is about 20 grams per square centimetre. They would be much reduced at 120,000 ft. (6 grams per square centimetre), an altitude which appears to be accessible with very large balloons.

The primary protons and α-particles, because of their smaller charge, penetrate to much lower altitudes. In collisions they disintegrate the nuclei which they strike and, in the process, lead to the creation of new forms of matter, the π-mesons. These are usually ejected with great speed and proceed downwards towards the earth. They commonly transform, whilst in flight, into a μ-meson and a neutral particle of small rest-mass, a neutrino. It is these μ-particles which form the 'hard' or 'penetrating' component of the cosmic radiation which is responsible for most of the residual ionisation in air at sea level. The μ-mesons are penetrating because unlike the π-mesons, they are able to traverse the nuclei with which they collide without interacting with them, and some of them reach great depths underground.

In addition to producing the charged π-mesons, the primary protons in making nuclear collisions also produce neutral π-particles. The neutral π-mesons are very short-lived and each transforms spontaneously into two quanta of radiation. Such a quantum, when it happens to pass near an atomic nucleus, can in turn transform into a pair of electrons, one positive and one negative; and the electrons can generate new photons in further collisions. A succession of such

This balloon can carry photographic plates to 90,000 ft. for cosmic ray researchers. A new balloon being built should rise to 22 miles.

processes results in the production of the well-known cascades of electrons and photons which form the 'soft', or easily absorbed, component of the cosmic radiation.

Although much longer lived than the π-mesons, some of the μ-mesons also decay in flight to produce electrons and neutrinos. The electrons contribute to the soft component, whilst the neutrinos join the similar particles arising from the decay of the π-mesons to produce a flux of neutral radiation which has a very weak interaction with matter, and of which the fate is at present unknown.

In addition to the π and μ-mesons, recent experiments at Manchester have shown that more massive types of mesons exist. Although they occur much less frequently than the π-mesons, the elucidation of their properties appears to be of great importance for the development of nuclear physics. The fast protons and α-particles generated by the cyclotrons are not sufficiently energetic to produce these more massive mesons, but this may become possible when the proton synchrotrons now under construction come into operation.

Only about 25 years ago was it generally recognised that part of the residual conductivity of a gas at sea level is due to the arrival from out of space of a radiation of great penetrating power. In the 1928 edition of *Conduction of Electricity in Gases*, J. J. Thomson and G. P. Thomson, commenting on this conclusion, remarked that: "It would be one of the romances of science if these obscure and prosaic minute leakages of electricity from well-insulated bodies should be the means by which the most fundamental problems in the evolution of the cosmos came to be investigated."

In the years which have passed, the study of what might, in the early days, have been regarded as a trivial phenomenon has, in fact, led us to the discovery of many new forms of matter and many new processes of fundamental physical importance. It has contributed to the development of a picture of the material universe as a system in a state of perpetual change and flux; a picture which stands in great contrast with that of our Victorian predecessors with their eternal and indestructible atoms. At the present time a number of widely divergent hypotheses, none of which is generally accepted, have been advanced to account for the origin of the cosmic radiation. It will, indeed, be of great interest if the contemporary studies of the primary radiation lead us—as the Thomsons suggested, and as present tendencies seem to indicate—to the study of some of the most fundamental problems in the evolution of the cosmos.

Exhibition of the Petroleum Industry

AN exhibition including every aspect of the petroleum industry with emphasis on exploration, on oil field, refinery and transport developments in many parts of the world, will be presented this summer at university centres in Britain. It is sponsored by the Shell Petroleum Company Ltd. and the Anglo-Iranian Oil Company Ltd.

It will be open to the public at the Imperial College of Science and Technology, S. Kensington, from April 6 to 21.

It will then tour the universities of Glasgow, Leeds and Cambridge, showing for approximately two weeks at each centre. It will be at the Royal Technical College, Glasgow, from May 4 to 19, at Leeds from June 20 to July 6, and at Cambridge from July 16 to 28.

Simpler Way to Make Cortisone announced

A MAJOR advance towards big-scale production of synthetic cortisone has been described to the American Chemical Society in a report by Dr. Edward C. Kendall, co-discoverer of the drug, and four of his co-workers at the Mayo Clinic, Rochester, Minnesota. An improved method of preparation permits the synthesis of the drug from bile acids without the use of osmium tetroxide, a scarce, expensive, and toxic material. "Cortisone may be made more cheaply and more abundantly" as a result of this development, the report declares, adding that "such large quantities of osmium are required and the supply is so limited that all pharmaceutical companies which would like to manufacture cortisone cannot secure the necessary amount of this rare element." The success of the method is the culmination of four years of research work at the Mayo Foundation.

Key to the preparation of cortisone, according to the report, is the introduction of a hydroxyl group into the proper molecular position, attaching it to the 17th carbon atom in a compound known as a *pregnane derivative* which is extracted from cattle bile.

Chemical Technology Books

A READER'S GUIDE to books on chemical technology has been published by the Library Association. This useful bibliography can be bought for 4*d*. a copy from MISS L. V. PAULIN, County Library, County Hall, Trent Bridge, Nottingham.

Third Programme gets New Transmitter

A NEW high-power transmitter and mast radiator are shortly to be put into service at Daventry for the Third Programme. This will bring improved reception of the Third, up till now unobtainable by many listeners. The installation has two of the latest Marconi 100 kW air-cooled transmitters, to give combined output of 200 kW but, to conform with the Copenhagen Plan, the actual power used will be limited to 150 kW. This newest design of broadcasting equipment is housed in the oldest surviving B.B.C. transmitting station and now occupies the space where 25 years ago the B.B.C. installed their first high-power transmitter for long-wave broadcasting—the famous 5XX.

A great advance in technique has been achieved in these transmitters in that *all* valves, including output valves, are air-cooled. A feature of the design allows the 15,000 cubic feet of air per minute, used for cooling, to be extracted warm and used to heat the transmitter hall.

Day-Glo Fluorescent Inks

IN the Feb. issue we published a "Progress of Science" item dealing with the new fluorescent printing inks. The firm concerned (Dane & Co. Ltd., of Stratford, London, E.15) has since announced that it is starting production in Britain of Day-Glo Fluorescent Inks, hitherto imported from America.

A New Hippopotamus

A NEW SPECIES of fossil hippopotamus has been discovered at the limeworks quarry in the Makapan Valley. This is reported by J. W. KITCHING of the University of Witwatersrand, Johannesburg, in *S. African Journal of Science* (Feb. 1951), who found a low molar tooth of the beast which is named *Hippopotamus makapanensis*.

The Bookshelf

The Life of the Vertebrates. By Prof. J. Z. Young, F.R.S. (London, Oxford University Press, 1950. 767 pp., 42*s*.)

THIS is a book which I should have found invaluable when I was at college. Our professor was no believer in textbooks: they were all out of date before they were published, he said, and what was more they never treated animals and plants as living organisms. There can be no doubt that he was quite right: nothing is more useless and dangerous than an obsolete textbook which gives a wrong perspective to the facts. More's the pity that textbooks get reprinted so many times: there is justification for the categorical conclusion that it would indeed be a mercy if a large proportion of British textbooks could be scrapped immediately. But to every student there comes a time when he needs a textbook of some sort; lecture notes are not completely self-sufficient or satisfying, and all too frequently they are more out of date than the average textbook. (Too many lectures are just a regurgitation of the things the lecturer jotted down when he was an undergraduate.)

Professor Young had all the objections to bad textbooks at the back of his mind when he started on this work—the preface and first chapter make that obvious. It is gratifying to be able to state that none of the usual objections can be raised here. The volume is in fact as near perfect as makes no odds. It satisfies the author's own criterion for a textbook ("it should be both accurate and general") and it copes very adequately with all the key facts which specialists have added to zoology in recent years. Perhaps there is a little too much about Prof. Young's own

speciality in the book, which is, however, understandable and scarcely to be regarded as grounds for criticism.

The book is far more readable than most zoology textbooks, even though the style of writing would hardly satisfy a literary critic. (It seems that we must reconcile ourselves to the inescapable observation that a study of modern science is destructive of the ability to write good English.) Few recent books have been more lavishly illustrated with first-class drawings; in particular, the pictures by Miss E. R. Turlington are truly beautiful. (Incidentally Walt Disney ought to look at her drawings; some of the more quaint animals she has depicted could add new zest to cartoon films!) The volume is an example of the very best in book production, and it is hard to see how today's printing and binding prices allow the book to be sold so cheaply.

The book is to be recommended for zoology undergraduates; every school library ought to have it, and if science masters consider that VI form students can afford two guineas it ought to be used by all scholarship candidates. Certainly the student who uses this book will learn the first essential of biological study—the realisation that animals are *living* organisms which are capable of variation and evolution. One wonders whether a somewhat condensed version could be produced for schools; such a book, at 21*s.* or 25*s.*, would be welcome in schools. Alternatively, would it be possible (by collecting excerpts and then listing them together with some new textual material) to produce a natural history book designed so as to make available to VI form students most of the fine illustrations in Prof. Young's book? Many of the sets of drawings deserve to be reproduced as wall charts.

WILLIAM E. DICK

Nature Through the Year. By Frances Pitt. (London, Macmillan, 1950, 300 pp. 18*s.*)

THE title is not very accurate, as the author concentrates on birds and mammals. But the book is pleasant reading: it is written in the form of a natural history calendar, with an essay on some such subject as "Birds of the Pond" and "Ailments of Wild Creatures" provided for every week of the year. Keen observation and anecdote are blended with a good collection of photographs, and the volume is to be recommended to all Frances Pitt fans.

Sourcebook on Atomic Energy. By Samuel Glasstone. (London, Macmillan, 1950, pp. 546, 24*s.*)

THIS book is an account in clear but not 'popular' style of the researches leading to our present knowledge of atomic energy. As might be expected by those familiar with his other books, Dr. Glasstone has produced a volume containing masses of accurate facts and one which remains very readable. The book should be of the greatest value to scientific writers and editors and even to students and scientists other than those specialising in the field of nuclear physics. It is, however, rather outside the scope of the layman.

W. J. ARROL

Advances in Radiochemistry. By E. Broda. Cambridge Monographs on Physics. (London, Cambridge University Press, 1950, pp. 152, 15*s.*)

IN this book, the author is really presenting us with an extensive and exceedingly well-documented review of the field of radiochemistry which he defines as "the chemistry of bodies which are detected by their nuclear radiations." The subject is one which requires knowledge of a great diversity of techniques and Dr. Broda is well qualified for his task.

It is inevitable that a book of only 140 pages which contains about 750 well-chosen references should suffer a little in so far as ease of presentation is concerned. All the same, the professional radiochemist will certainly wish to read the book and many other chemists will gain from it an excellent appreciation of a somewhat specialised subject.

W. J. ARROL

Birds and Men. By E. M. Nicholson. (London, Collins, 1951, 256 pp., 42 colour and 41 black-and-white photographs, 21*s.*)

E. M. (MAX) NICHOLSON is a top Civil

A picture of Saponaria from Part 5 of Stella Ross-Craig's "Drawings of British Plants." (See next page.)

servant in charge of the office of the Lord President, who is responsible for the D.S.I.R. and certain other state-sponsored research activity. In his spare time he is a bird-watcher, in fact one of our leading bird-watchers. He is a careful observer and also a systematic collector of facts about birds. This is his latest book; it is, in the opinion of this reviewer, his best book, and it is certainly the best general book in the New Naturalist series since Fitter's *London Natural History*. The colour plates are exceptionally good; the black-and-white photographs might have looked better if they had been printed by photogravure instead of by letterpress.

Brown Men and Red Sand. By Charles P. Mountford. (London, Phoenix House, 1950, 192 pp., 63 illustrations, 18*s*.)

THIS is a travel book with great scientific interest as the author is an ethnologist who has studied the life of Australian aborigines—a unique Survival of the Stone Age. He is also an expert photographer (he has produced films showing the aboriginal way of life), and this volume contains a great many of his best still pictures. There is also some keen observation on plants and animals of the Central Australian desert.

Books on British Flowers

THERE are many people who, while not trained botanists, like to be able to name the wild plants which they find. With suitable books, and with but slight knowledge of formal botany, this naming is not difficult, at any rate with plants with reasonably large flowers, though it must be remembered that some plants (such as the sedges, rushes and grasses) are difficult, but by no means impossible once experience has been gained. It is well to accept from the start the idea of learning the Latin or latinised names, as well as the popular names when they exist. Very many wild plants have no popular names, though they have often been provided with invented book-names which are often just a translation of the Latin names, and are of no great value. There is little substance in the objection to the use of the Latin names. So many of these names are now generally familiar, on seed packets, in horticultural articles in the Press, and even in common speech (e.g. *Aspidistra*) that they can no longer be regarded as outlandish. It is no more difficult to learn and remember these names than it is to learn and remember the special words used in dealing with radio or aeroplanes, and especially in dealing with fashions in female attire. And, the systematic names have the great advantage that they are universally understood by botanists. It is true that if reference is made to a number of systematic books, different Latin names may be found which clearly apply to one and the same kind of plant. Many plants have been described and named by several authors, and, in consequence, there may be several names. Of these, one only is valid, the rest are synonyms, but, up to the present, it has not been possible to get international agreement on what is the valid name. Provided the amateur knows that this is the position, he need not trouble himself much about it, though he would be well advised to settle on one book as the source of his names; for that purpose, Bentham and Hooker's *Handbook of the British Flora* cannot be bettered.

So far as they can do it, professional botanists who are specially concerned with the naming of plants try to match their specimens against the authentic specimens used by the authority who first properly named the plant. This method is not normally available to amateurs, who must therefore turn to books. That means that they try to match their specimens against pictures, or descriptions, or both, and if the matching is satisfactory, then the name attached to the picture or description is considered to be that for the specimen. Reliance on pictures alone is unwise; matching the specimen with a good description is better, for this cannot be done unless the specimen is thoroughly examined, whereas comparison with pictures only leads to superficial work and to frequent mistakes.

Most of the books used in naming plants are provided with keys, and the hope is that the reader who follows the key accurately will be brought, more or less expeditiously and conveniently, to the name he is seeking. Usually, the keys use features of the plant which are readily seen, but even with the simplest keys thorough examination is essential. Glossaries in the books will help in the understanding of the keys.

British flowering plants have been studied for a long time, and there are available a number of books of various merit from which our plants can be named. The choice of a book depends a good deal on what the worker has in mind. If just a name is needed, the simpler the book the better, though from such a book the naming may be approximate rather than accurate. If, on the other hand, the name is to be used in the preparation of work intended for publication, then, except in very clear instances, not only should as many books as possible be consulted, but the advice of an expert botanist should be sought. There is another point to be borne in mind. During the last century or so, many plants have been brought into cultivation from abroad, and some of these are not now uncommon as escapes from cultivation, while others have been planted in natural surroundings, and to the inexperienced may seem to be wild plants. Few of these introductions and escapes are described in works on the British flora, though those books often make it possible to determine at least the family to which the problematic plant belongs, and at any rate they will show that the plant is not a member of the British flora; but it must be admitted that these alien plants are often a trial to the inexperienced field botanist. A general warning worth remembering is that if the use of the book indicates that the plant under examination is a very rare one, then it is probable, though of course not certain, that a mistake has been made in using the keys; it is surprising how often, until experience has been gained, very rare plants are found by the beginner.

A few books are listed below, with some comments on them. In these unsettled times, it is not possible to state certainly that all these books are in print, nor to give reliable prices. Some may be obtainable only in the second-hand market. Inquiry at a large booksellers should settle such matters.

Watts, W. M. *A School Flora*. Longmans, Green & Co. A simple, easy book to use. It does not include all the British plants.

Skene, Macgregor. *A Flower Book for the Pocket*. Oxford University Press. Another simple book which describes many, but not all of the British flowering plants; it contains a large number of attractive coloured illustrations.

Bonnier, G. (translated and adapted by E. Mellor). *British Flora*. J. M. Dent & Sons. A most convenient book consisting largely of keys based on the obvious features of the plants. It covers all British flowering plants and ferns, as well as a number of cultivated plants, and contains much information of value to the amateur botanist. The small drawings, of which there are some 2300, are clear and informative, though some of them are printed in awkward situations.

Bentham, G., and Hooker, J. D. *Handbook of the British Flora*. L. Reeve & Co., Ashford, Kent, with the companion volumes:

Fitch, W. H., and Smith, W. G. *Illustrations of the British Flora*.

Butcher, R. W., and Strudwick, F. E. *Further Illustrations of British Plants*.

These three volumes are often appropriately called the Botanist's Bible. They cover the British vascular plants very thoroughly and accurately, and, once the technique has been learned, are straightforward in use.

Babington, C. C. *Manual of British Botany*, Gurney and Jackson. A good, accurate manual, which, however, needs experience if it is to be used effectively. It, and the foregoing three volumes, are specially recommended to the amateur who intends to make a real study of botany.

Reference may be made to the books by J. Hutchinson in the Penguin books, which cover a part only of the field, and to the *Drawings of British Plants*, by Miss Stella Ross-Craig, now in course of publication by G. Bell and Sons; the whole set of drawings will not be available for some time yet; they are excellent.

B. BARNES.

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